

# 05

Illustration of NBS  
impact indicator  
selection and application

Appendix of Methods

**What constitutes NBS monitoring?**  
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**How can I execute monitoring and impact assessment activities?**  
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**How do I select appropriate indicators of NBS impact?**

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for Disaster Risk Reduction?

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gather, and how should I  
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## 5 APPLICATION OF THE NBS IMPACT EVALUATION FRAMEWORK: NBS PERFORMANCE AND IMPACT EVALUATION CASE STUDIES

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## Summary

### ***What is this chapter about?***

Selecting appropriate indicators of NBS performance and impact can be challenging, and is context-dependent. In this chapter, we present case studies from a variety of NBS demonstrations across Europe and Asia that illustrate the application of the NBS indicators and methods presented in Chapter 4 and thoroughly described in *Evaluating the Impact of Nature-Based Solutions: Appendix of Methods*. Each case study presents a brief NBS description, reasons for the selection of specific indicators for that particular NBS and a brief overview of the ways the indicators are applied and/or monitored. The case studies describe the stakeholders involved in co-design and co-monitoring of NBS and discuss the barriers and lessons learned during or after the process. Each case study provides key references for further reading.

The case studies in this chapter focus on the selection of recommended indicators for NBS performance and impact, which are generally of primary importance when creating NBS monitoring and evaluation plans. The case studies further demonstrate how and why additional indicators can be selected to reflect particular objectives of projects and local challenges.

### ***How can I use this chapter in my work with NBS?***

The examples of indicator application illustrate the practice of selecting the appropriate indicators from the pool of indicators presented in Chapter 4. This information will aid in understanding *why* and *how* to select indicators for evaluating NBS performance and impact.

Information from the case studies presented in Chapter 5 can be used to support planning, indicator selection, execution and monitoring of NBS.

### ***When should I use this knowledge in my work with NBS?***

We recommend consulting the case studies during the early stages of NBS planning and deployment, and well before selecting indicators and establishing NBS monitoring.

### ***How does this chapter link with the other parts of the handbook?***

Chapter 5 complements the presentation of NBS indicators (Chapter 4 and Appendix of Methods) by presenting explicit examples tied to concrete NBS actions. This chapter assists in making a selection of the indicators listed under Chapter 4. It provides insights into NBS monitoring approaches described in Chapters 2, 3 and 6, and alludes to data generation techniques discussed in Chapter 7.

## **5.1 Introduction to holistic NBS impact assessment using the framework of recommended indicators**

A series of concrete examples of the application of Recommended indicators are provided here to illustrate the type of narrative it is possible to develop from the gathered evidence. Specific messages regarding NBS outcomes can be tailored for different stakeholders, e.g., citizens, investors, policy-makers, etc. The Recommended indicators illustrated in the following examples reflect the multi-functionality of NBS and highlight synergies between outcomes in different societal challenge areas.

For the sake of demonstrating the importance of each individual indicator, the case studies presented herein describe only the basis for the selection of one, or in some cases several, either Recommended or Additional indicators (Chapter 4). This approach was adopted to highlight the importance of the Recommended indicators as the primary indicators to be addressed when creating NBS monitoring and evaluation plans, and to emphasise the value of selecting unique and complementing Additional indicators based on projects' objectives and the local challenges NBS aim to address. The case studies were selected per projects' suggestions given their relative advancement in NBS and their monitoring strategy implementation. It should be noted that although the case studies present indicators associated with a specific impact (e.g., water quality or air quality), the NBS exhibit a much greater number of impacts and co-benefits (e.g., on biodiversity, health and well-being), which must be considered when designing a monitoring strategy.

It is important to note that selected indicators of NBS impact should capture not only the range of different NBS co-benefits, but should also shed light on trade-offs for different social groups and between different challenge areas. For example, issues of gentrification, social justice and similar should be carefully considered in order to gain an understanding of both benefits and trade-offs, and to identify potential issues in order to develop effective mitigation strategies.

This Chapter is presented as a series of case studies related to the selection of [Recommended indicators](#) and [Additional indicators](#). Table 6-1 lists the Recommended and Additional indicators illustrated in the case studies.

**Table 5-1.** Case studies illustrating the selection of Recommended and Additional indicators.

Challenge	Recommended indicator case study	Additional indicator case study
Climate Resilience	<a href="#">Carbon storage</a>	<a href="#">Urban Heat Island incidence</a>
Water Management	<a href="#">Water quality: total suspended solids (TSS) content; Nitrogen and phosphorus concentration or load</a>	–
Natural and Climate Hazards	–	<a href="#">Flood risk</a>
Green Space Management	<a href="#">Green space accessibility</a>	<a href="#">Walkability;</a> <a href="#">Annual trend in vegetation cover;</a> <a href="#">Nature-based recreation;</a> <a href="#">Land composition</a>
Biodiversity Enhancement	<a href="#">Green infrastructure connectivity</a>	<a href="#">Number of conservation priority species</a>
Air Quality	<a href="#">PM<sub>10</sub> and PM<sub>2.5</sub> concentrations</a>	<a href="#">Trends in NO<sub>x</sub> and SO<sub>x</sub> emissions</a>
Knowledge and Social Capacity Building for Sustainable Urban Transformation	–	<a href="#">Connectedness to nature</a>
Social Justice and Social Cohesion	–	<a href="#">Perceived social support</a>
Health and Wellbeing	<a href="#">Level of outdoor physical activity (min/week);</a> <a href="#">Level of chronic stress ("Perceived stress");</a> <a href="#">Self-reported general wellbeing</a>	<a href="#">Prevalence, incidence, morbidity of chronic stress;</a> <a href="#">Perceived chronic loneliness</a>



### 5.1.1 Recommended indicators case study from Tampere, Finland

NBS Name and Location	Vuores stormwater management system (incl. retention pond, biofilter, alluvial meadows) Tampere (Finland)
<b>Brief description of NBS</b>	<p>The Vuores district is a new district in the City of Tampere (Finland), featuring an extensive stormwater management system (in Virolainen- and Tervaslampi Parks) comprising of several NBS, including the retention pond, biofilter, and alluvial meadows. The Vuores catchment drains to the Lake Koijärvi, so preservation of the lake water quality was the main driver for creating a comprehensive urban runoff management (quality and quantity) system.</p> <p>Virolainen Park:</p> <ul style="list-style-type: none"> <li>- Biofilter (with sand as a filtering media): Treatment of urban runoff and runoff from a dog park</li> </ul> <p>Tervaslampi Park:</p> <ul style="list-style-type: none"> <li>- Retention pond: Treatment (retention and sedimentation) of urban runoff from new housing area</li> <li>- Alluvial meadows: Space for retention of the urban runoff at times of heavy rainfall</li> </ul> <p>Useful links:  <a href="https://unalab.eu/en/our-cities/city-tampere">https://unalab.eu/en/our-cities/city-tampere</a>  <a href="http://www.tampere.fi/unalab">www.tampere.fi/unalab</a> (in Finnish)</p>
<b>Indicators of relevance</b>	<p><b>3.2 Water quality: total suspended solids (TSS) content</b></p> <p><b>3.3 Nitrogen and phosphorus concentration or load</b></p>
<b>Explanation for selection of Indicators in this case</b>	<p>Due to the densification and urbanisation of the newly built areas, stormwater quality management was the main priority for the City of Tampere to prevent the water quality deterioration of the local waterbodies. TSS content and nutrient (N and P) concentrations comprise the critical water quality constituents determining the urban runoff quality entering the surface waterbodies and their possible adverse effects on the aquatic environment (e.g., eutrophication). The NBS addressing water quality further aid in delivering a variety of co-benefits, including water quantity management, enhancement of local biodiversity, and contributing to increased local environmental awareness.</p>
<b>Description of Indicator Application</b>	<p>Multiple NBS across the Vuores district are equipped with the online water quality sensors continuously measuring a variety of water quality parameters. Each sensor is capable of measuring the basic water quality parameters, including nitrate-nitrogen (NO<sub>3</sub>-N) concentrations. Subsequently, the sensors calculate total phosphorus concentration based on the turbidity measurements, and total nitrogen concentration based on the nitrate-nitrogen measurements. Manual sampling for TSS content is performed at regular time intervals.</p>

<b>Stakeholders involved</b>	City representatives, citizens, NGOs, public and private sector actors (incl. research organisations), and representatives from universities
<b>Barriers encountered and lessons learned</b>	<p>Barriers to 'physical' NBS implementation in Tampere included the biofilter space requirements in Virolainen Park. Some residents found the alluvial meadows and wetland vegetation (Figure 5-1) lacking the aesthetics. However, this was overcome through awareness raising with the information signs and during the co-creation workshops.</p> <p>The stakeholder engagement proved to be successful after a series of co-creation workshops that resulted in the change of plans for the Vuores area development, additionally considering local biodiversity, health and water management aspects (Särkilahti 2019).</p>
<b>Case study authors</b>	<p>Maria Dubovik<sup>1</sup> (<a href="mailto:maria.dubovik@vtt.fi">maria.dubovik@vtt.fi</a>), Ville Rinta-Hiiro<sup>1</sup>, Maarit Särkilahti<sup>2</sup>, Salla Leppänen<sup>2</sup></p> <p><sup>1</sup>VTT Technical Research Centre of Finland, Espoo, Finland</p> <p><sup>2</sup>City of Tampere, Finland</p>
<b>References</b>	<p>Särkilahti, M., 'Co-creating nature based solutions in EU project demonstration city Tampere', <i>Rakennustekniikka</i>, 2019. Available from: <a href="https://www.ril.fi/fi/rakennustekniikka/teemat/co-creating-nature-based-solutions-in-eu-project-demonstration-city-tampere.html">https://www.ril.fi/fi/rakennustekniikka/teemat/co-creating-nature-based-solutions-in-eu-project-demonstration-city-tampere.html</a></p>



**Figure 5-1.** Nature-based solutions in Vuores Central Park (© City of Tampere).

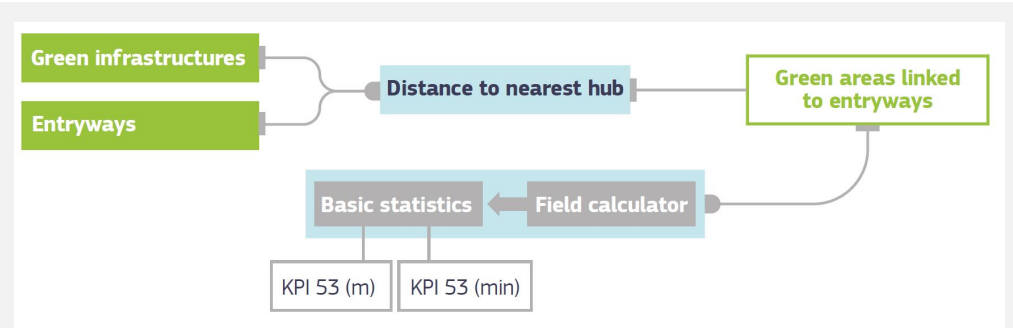
### 5.1.2 Recommended indicators case study from Valladolid, Spain

NBS name and location	<p>Urban carbon sink</p> <p><b>Valladolid Demo Site.</b></p> <p><b>The Urban Carbon Sink is located in the eastern part of the municipality of Valladolid, in the neighbourhood known as Los Santos-Pilarica (Sector 50, "Los Santos 2").</b></p>
<p><b>Brief description of NBS</b></p>	<p>The Urban Carbon Sink (UCS; Figure 5-2) is conceived as an urban forest in which species have been selected mainly for their ability to fix carbon. Therefore it is a nature-based solution for the over-accumulation of carbon dioxide in cities' atmosphere.</p> <p>The design of the UCS is embedded into another projected NBS, the Floodable Park. It will consist in the installation of urban woodland (initially planned planting 1,500 trees in a 40,000 m<sup>2</sup> surface) with appropriate species adapted to temporary flood condition and with high capacity of carbon sequestration (<i>Fraxinus</i> spp., <i>Betula</i> spp., <i>Salix</i> spp., <i>Populus</i> spp., etc.). Trees of this forest will be allocated in specific arboreal series.</p> <p>This area will be a new urban carbon sink and will form a new urban ecosystem to preserve the biodiversity. Likewise, this woodland will provide biomass to energy use with social and economic purposes.</p> <p>Expected impacts: The UCS will be located close to industrial and traffic areas, which act as a source of carbon dioxide emissions due to combustion processes. This NBS is proposed to compensate the emissions of this greenhouse gas, capturing it in the form of biomass.</p> <p>In order to achieve this effect, it is necessary to include specific criteria for taxon selection composition and typology of them during designing stage of UCS. Likewise, it will be essential to take into account to establish a management plan (pruning, spacing, etc.).</p> <p>Multicriteria species assessment is required, focused on C fixation capacity, in addition with other aspects, such as native vegetation, easy management, aesthetics, health, ecological coherence and integrity criteria. Impacts derived from UCS implementation must be evaluated on medium-long term, since to C fixation capacity of the species is highly related to the maturity grade of the taxa.</p>



**Figure 5-2.** Urban Carbon Sink conceptual design (URBAN GreenUP project)

<p><b>Indicators of relevance</b></p>	<p><b>1.1 Total carbon removed or stored in vegetation and soil per unit area per unit time</b>  Temperature decrease  Heatwave risk  Green space distribution (m<sup>2</sup>/capita)  Green space distribution (km cycle lane/capita)  <b>7.1 Green space accessibility</b>  Green areas sustainability  Elderly people life quality  <b>9.1 Green infrastructure connectivity</b>  Pollinator species increase</p>
<p><b>Explanation for selection of Indicators</b></p>	<p>This NBS will improve the accessibility to green space value in the area for the surrounded population, with 40.000 m<sup>2</sup> of new available green space.</p> <p>Other indicators that are related with this NBS are those related with Carbon storage, as it is the main purpose of this NBS.</p>
<p><b>Description of Indicator Application</b></p>	<p>In this case, the main indicator for impact assessment is 01.01 and 01.02 and additionally the other ones. This indicator will need an spatial and statistical analysis, following the following algorithm (Figure 5-3):</p>



**Figure 5-3.** Suggested algorithm for the QGIS process as defined in Deliverable D2.4: Monitoring Program to Valladolid from the URBAN GreenUP Project.

In this case, “Green infrastructures” is referred to the arriving point and “entryways” to departure point.

<b>Stakeholders involved</b>	Different municipality areas (at least urbanism, environment and heritage), car park property, construction and gardening companies, River Duero Basin (it is located in the Esgueva River bank).
<b>Barriers encountered and lessons learned</b>	Main barriers are located in the availability of data required for this Indicator.
<b>Case study authors</b>	<p>Raúl Sánchez<sup>1</sup>, Jose Feroso<sup>1</sup>, Francisco Verdugo<sup>1</sup>, Raquel Marijuan<sup>1</sup>, Silvia Gómez, María González<sup>1</sup>, José María Sanz<sup>1</sup>, Esther San José<sup>1</sup></p> <p><sup>1</sup>CARTIF Foundation. P.T. Boecillo, 205, 47151, Boecillo, Valladolid, Spain</p>

5.1.3 Recommended indicators case study from Guildford, UK

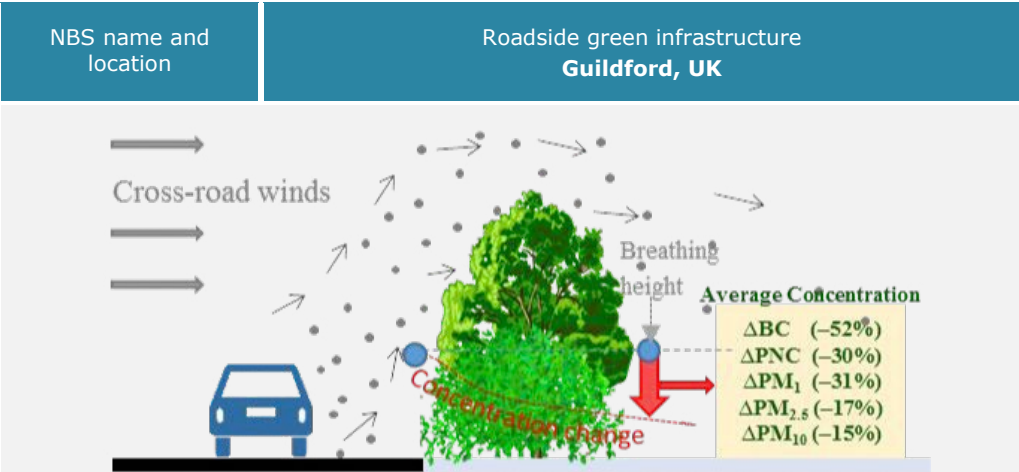


Figure 5-4. Roadside green infrastructure.

Brief description of NBS

**Roadside Green Infrastructure** (Figure 5-4) includes trees, hedges, individual shrubs, green walls, and green roofs. The focus of the iSCAPE pilot in Guildford (UK) was air pollution abatement and in specific on particulate matter (PM), which is composed of particles such as black carbon (BC). The pilot focused on near-road environments, where vegetation can act as a barrier between traffic emissions and pedestrians (figure below), by collecting pollutants and/or redirecting the flow of polluted air (Abhijith et al., 2017; Kumar et al., 2019; Riondato et al., 2020; Tiwari et al., 2019). This study performed as part of iSCAPE (GA n° 689954) pioneered the adoption of this kind of nature based solution as a passive control system for roadside pollution in urban street canyon and open road settings.

The pilot assessed through monitoring and modelling different combinations of trees, hedges and individual shrubs to assess their performances in urban street canyon and open road settings in terms of abatement of road traffic particulate matter (PM).

Project results show that green barriers can produce a reduction of concentration of Black Carbon up to 52%,  $PM_{10}$  up to 31%,  $PM_{2.5}$  up to 17%,  $PM_{10}$  up to 15%.

A series of design parameters were also created for both urban street canyon and open road settings to help planners in the effective deployment of this kind of air pollution abatement intervention (Kumar et al., 2019):

Considerations for urban street canyon green infrastructure	
Design parameter	Considerations
Location	If the prime objective is to reduce exposure for pedestrians or cyclists, hedges should be planted close to the road, between the

	road and footpath/bike path. Green walls can be constructed on the pillars of flyovers, retaining walls and other boundary walls.
Selection of vegetation	In deep street canyons, no forms of vegetation except green walls are recommended. In mid-depth street canyons (Table 4), shrubs or hedges and green walls can be planted, but trees are not recommended. Large, dense trees should be avoided in all street canyons, but smaller or lighter-crowned trees may be planted in shallow street canyons.
Spacing	Continuous hedges (with no gaps or spacing) provide a better reduction in exposure for pedestrians and cyclists. If trees are to be planted (shallow canyons only), they should be spaced generously apart from one another.
Height	For hedges, a height of around 2m is recommended.
Thickness	For hedges, a thickness of 1.5m or more is recommended.
Density	In street canyons, a higher density for hedges and lower density for trees is recommended.

#### Considerations for open road green infrastructure

Design parameter	Considerations
Location	Hedgerows should be planted between the road and walkways or dwellings and in front of trees (if present); this configuration offers the maximum reduction of exposure.
Spacing	Barriers with no gaps provide better downwind exposure reduction.
Height	Where possible, it is recommended that the combined hedge-tree barrier or green wall has a height of 5m or more. Vegetation barriers with greater height result in increased pedestrian-side pollutant reductions. A minimum height of 1.5m is recommended.
Thickness	The vegetation should be as thick as possible; thicker vegetation barriers offer greater exposure reduction. If possible, a thickness of more than 5m is recommended.
Density	High-density vegetation barriers are generally better for reducing exposure levels downwind.

#### Indicators of relevance

Monetary values: value of air pollution reduction; total monetary value of urban forests including air quality, run-off mitigation, energy savings, and increase in property values.

##### **11.1 Air quality parameters (Particulate Matter)<sup>†</sup>**

Concentration of particulate matter (PM<sub>2.5</sub> and PM<sub>10</sub>) at respiration height along roadways and streets.

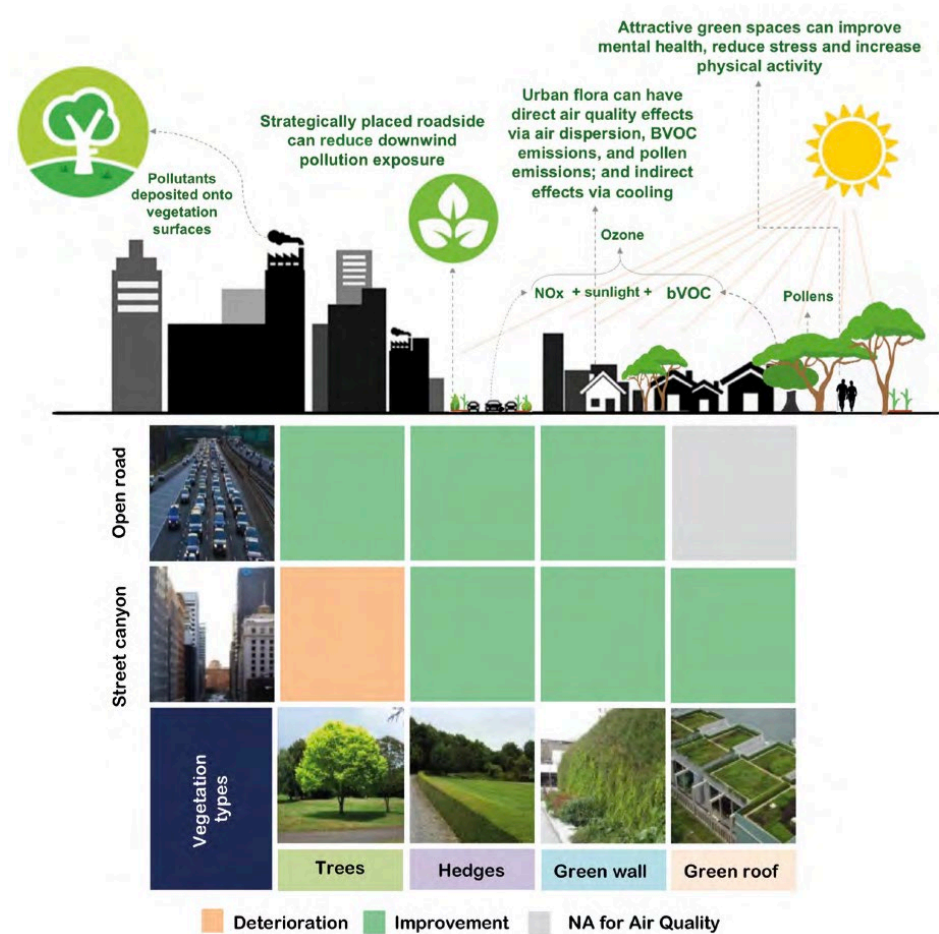
<sup>†</sup>*Contributes to evaluating indicators 12.7/12.8*

#### Explanation for selection of Indicators

In future, if this NBS is widely installed it can be used recommended indicators for Air Quality challenges (Figure 5-5). Recommended indicators have a scale of measurement from district to region and they have not sensibility enough to study the impact of this NBS. Therefore, in the meantime it is needed additional indicators to assess the impact on air pollutants emission reduction with indicators such as the ones mentioned before.

<b>Description of Indicator Application</b>	<p>In this case, the main indicators for impact assessment is 6.11 and 6.13. 6.11 implies the installation of sensors for continuous monitoring of PM on the two sides of the deployed green barrier NBS.</p> <p>It is also recommended to complement the monitoring campaign with modelling to account for the impact of local climate.</p>
<b>Stakeholders involved</b>	A wide range of stakeholders including local authorities, academia and local community which were involved in co-design and co-monitoring activities.
<b>Barriers encountered and lessons learned</b>	<p>The main challenge was the initial engagement of the stakeholders for the co-design and co-monitoring activities part of the Living Lab framework embraced by iSCAPE. The development of a solid strategy resulted in a very high engagement of the stakeholders in this pilot, which allowed to produce the adequate bottom-up support to push the findings from the pilot into policy within the lifetime of the project. The findings were endorsed and operationalised as policy by the Mayor of London (<a href="https://www.london.gov.uk/sites/default/files/green_infrastruture_air_pollution_may_19.pdf">https://www.london.gov.uk/sites/default/files/green_infrastruture_air_pollution_may_19.pdf</a>). The pilot clearly demonstrated the advantages of involving a wide range of stakeholders in the various stages of the design, development and monitoring of NBS.</p> <p>It also clearly demonstrated the effectiveness, if appropriately deployed, of common elements of green infrastructure as passive control systems for air pollution.</p>
<b>Case study authors</b>	<p>Francesco Pilla<sup>1</sup>, Prashant Kumar<sup>2</sup></p> <p><sup>1</sup><i>Spatial Dynamics Lab, University College Dublin, Ireland</i></p> <p><sup>2</sup><i>Global Centre for Clean Air Research, University of Surrey, UK</i></p>
<b>References</b>	<p>Abhijith, K.V., Kumar, P., Gallagher, J., McNabola, A., Baldauf, R., Pilla, F., Broderick, B., Di Sabatino, S. and Pulvirenti, B., 'Air pollution abatement performances of green infrastructure in open road and built-up street canyon environments–A review', <i>Atmospheric Environment</i>, Vol. 162, 2017, pp. 71-86.</p> <p>Kumar, P., Abhijith, K.V. and Barwise, Y., <i>Implementing green infrastructure for air pollution abatement: General recommendations for management and plant species selection</i>, 2019.</p> <p>Riondato, E., Pilla, F., Basu, A.S. and Basu, B., 'Investigating the effect of trees on urban quality in Dublin by combining air monitoring with i-Tree Eco model', <i>Sustainable Cities and Society</i>, Vol. 61, 2020, p. 102356.</p> <p>Tiwari, A., Kumar, P., Baldauf, R., Zhang, K.M., Pilla, F., Di Sabatino, S., Brattich, E. and Pulvirenti, B., 'Considerations for evaluating green infrastructure impacts in microscale and macroscale air pollution dispersion models', <i>Science of The Total Environment</i>, Vol. 672, 2019, pp. 410-426.</p>





**Figure 5-5.** An overview of the relationship between air quality and green infrastructure with a matrix offering local-scale implementation impacts (adapted from Abhijith et al. 2017 and Kumar et al. 2019).

#### 5.1.4 Recommended indicators case study from Genk, Belgium

NBS name and location	Schansbroek Park (Genk, Belgium)
<b>Brief description of NBS</b>	Schansbroek Park lies near the source zone of the Stiemerbeek River and near the coal mine of Waterschei. The park is an example of NBS for brownfield regeneration (Figure 5-6), as the area was surrounded by mining activities that were severely affected natural water management contributing to pollution and flooding for local residents (Connecting Nature, 2020). The topography of the area was altered by mining operations and to

	<p>protect local residences, rainfall and groundwater has had to be pumped into the Stiemberbeek River. This severe hydrological impact caused water shortage for natural wetland areas negatively impacting their biodiversity. Regarding its attractiveness, although the area has a 16th century defensive structure 'De Schans', the surroundings were unattractive and there was a lack of recreational infrastructure for visitors, residents and workers (Green4Grey, 2020).</p> <p>In view of the state of the area, the Flemish Land Agency (VLM) together with the city of Genk began a participatory redesign, where the suggestions made by local citizens (i.e., allotments, children's play areas, cycling / hiking trails, picnic and meeting areas) were included in the new plan (Hölscher et al., 2019). In addition, the redesign involved measures to recreate a 'wet ecotope' by restoring a natural dam and ponds, and transforming an artificial reservoir from the former mine (Connecting Nature, 2020).</p> <p>The environmental benefits were powerful, since the biodiversity and natural conservation of the area were optimized, reducing flooding and improving water quality. Furthermore, the fact of regulating the floods provided thermal comfort zones. The benefits were not only in the environmental dimension but also in public governance and wellbeing. The new park enhanced the aesthetics of the area, with new spaces to exercise and meet up. Thus, it became an attractive space for residents and workers of the neighbouring Thorpark that allowed citizens to reconnect with nature, improving physical and mental wellbeing. The fact of having conducted participatory planning contributed to promoting social cohesion and environmental stewardship (Connecting Nature, 2020).</p>
<b>Indicators of relevance</b>	<p><b>21.1 Level of outdoor physical activity (min/week)</b>  <b>21.2 Level of chronic stress ("Perceived stress")</b>  <b>21.4 Self-reported general wellbeing</b>  Frequency of social activities in outdoor spaces</p>
<b>Description of Indicator Application</b>	<p>The indicators selected to assess the health and wellbeing dimension in Schansbroek Park form a coherent framework that allows analysing the NBS effects on citizens.</p> <p>Starting with the level of outdoor physical activity, defined as self-reported participation in organized or unorganized sport or exercise, outdoors, at least once a week (Schipperijn et al., 2013), is a fundamental indicator to discover if the new redesign of Schansbroek Park, with its cycling and hiking routes, improves the healthy habits of users. Knowing the weekly physical activity levels allow a broad vision of the health and well-being of the area, since numerous studies in various countries have shown that access to, and use of, urban green space contributes to increased physical activity, wellbeing, higher rates of recreational walking and reduced sedentary time (Almanza et al., 2012; Braubach et al., 2017; Lachowycz and Jones, 2014; Sallis et al., 2016; Schipperijn et al., 2013; Sugiyama et al., 2014).</p>

	<p>Complementarily, the indicator of frequency of social activities in outdoor spaces, follows the same line, since during the participatory design process of the new area of Schansbroek, neighbours and workers suggested including places that allow social interaction. This interaction is now possible in the park and represents a great advance in terms of health and well-being assessment, as green spaces contribute to social cohesion, fostering social interactions and engagement, promoting a sense of community (Jennings and Bamkole, 2019; Prezza et al., 2001).</p> <p>Chronic stress and self-reported wellbeing complete the vision on the potential impacts of Schansbroek Park can produce in terms of well-being, specifically mental health. A growing body of empirical evidence documents the relationship between connection and contact with green spaces and a greater subjective well-being (Frumkin et al., 2017; Howell et al., 2011; Howell and Passmore, 2013; Larson et al., 2016; MacKerron and Maurato, 2013; Pritchard et al., 2020; Wendelboe-Nelson et al., 2019; Zhang et al., 2014). Contact with natural urban environments can provide psychological relaxation and stress alleviation, enhancing immune function, stimulating social cohesion, supporting physical activity, and reducing exposure to air pollutants, noise and excessive heat (Braubach et al., 2017; Hartig et al., 2014).</p> <p>In addition, other indicators were implemented in the field of Health and Wellbeing, corresponding to indicators: Perceived restorativeness of NBS and Incidence of obesity among adults, of the taskforce.</p>
<p><b>Description of Additional Indicator Application</b></p>	<p>Methodology and data analysis require high expertise in psycho-social research but quantitative data collection requires no expertise. During the Connecting Nature project, the data gathering is conducted after the NBS implementation, but it allows making comparisons between different areas of the city or population groups (i.e., users versus no users). Indicator application was as follows:</p> <p><i>Level of outdoor physical activity (min/week)</i></p> <p>☒ <i>Quantitative P:</i> Scale/Scale inventory/Questionnaire (survey procedure, paper-and-pencil administration, computer-based administration)</p> <ul style="list-style-type: none"> <li>○ <i>T: International Physical Activity Questionnaire (IPAQ) (<a href="#">International Physical Activity Questionnaires, n.d.</a>).</i> IPAQ (both long - 27 items, and short form - 7 items) assesses physical activity undertaken across a comprehensive set of domains including: <ul style="list-style-type: none"> <li>• leisure time physical activity</li> <li>• domestic and gardening (yard) activities</li> <li>• work-related physical activity</li> <li>• transport-related physical activity</li> </ul> </li> </ul> <p><i>Frequency of social activities in outdoor spaces</i></p> <p>☒ <i>Quantitative P:</i> Scale/Scale inventory/Questionnaire (survey procedure, paper-and-pencil administration, computer-based administration)</p>

- T: Ad hoc question adapted from Bloesma et al. (2018): How often do you intentionally go to a green environment (not your own garden or Schansbroek Park) for social activities (meeting family or friends, chatting with neighbours, having a picnic, playing board games)?

#### *Level of chronic stress ("Perceived stress")*

- ☒ *Quantitative P:* Scale/Scale inventory/Questionnaire (survey procedure, paper-and-pencil administration, computer-based administration)
  - T: *Perceived Stress Scale* (Cohen et al. 1983), a self-report measure intended to capture the degree to which persons perceive situations in their life as excessively stressful relative to their ability to cope. Within Connecting Nature, the PSS-10 version was used because it was established as the most recommended form of PSS (as cited in Taylor, 2015, p. 90).

#### *Self-reported general wellbeing*

- ☒ *Quantitative P:* Scale/Scale inventory/Questionnaire (survey procedure, paper-and-pencil administration, computer-based administration)
  - T: *Satisfaction with Life Scale* (Diener et al., 1985), a 7-point scale comprising 5 items that measure individual's general satisfaction with own life as a cognitive-judgmental process (i.e., based on a comparison with a standard that individual had set for him/herself).

#### *Perceived restorativeness of NBS*

- ☒ *Quantitative P:* Scale/Scale inventory/Questionnaire (survey procedure, paper-and-pencil administration, computer-based administration)
  - T: *Perceived Restorativeness Scale* (the short, PRS - 11) (Pasini et al., 2014), a shorter, parallel version of the Perceived Restorativeness Scale (PRS - 26) (Hartig et al., 1997), developed to address original psychometric limitations; PRS is based on the Attention Restoration Theory (ART; Kaplan, 1995) and its short version measures an individual's perception of 4 restorative factors assumed to be present to a greater or lesser extent in the environment, namely physical and/or psychological "being-away" from demands on directed attention, "fascination" a type of attention assumed to be effortless and without capacity limitations, the "coherence" and "scope" perceived in an environment. Participant's judgments are made on a 0 to 10-point scale.

#### *Incidence of obesity among adults*

- ☒ *Quantitative P:* Scale/Scale inventory/Questionnaire (survey procedure, paper-and-pencil administration, computer-based administration)
  - T: *Measurements of Body mass index (BMI)*. A ratio of weight to height that is calculated by the following formula:  $BMI = \text{weight (kg)} \div \text{height (m)}^2$ . For adults,

	<p>BMIs in the range of 18.5 to 24.9 are considered to be healthy – and associated with the lowest risk of mortality and morbidity. Overweight is defined as a BMI of 25.0 to 29.9; obesity is defined as a BMI of at least 30, with 3 sub-categories (Class I, Class II, and Class III) that are associated with increasing risk of cardiovascular disease, type 2 diabetes, and all-cause mortality (Bhrem and D'Alessio, 2014).</p>
<b>Stakeholders involved</b>	<p><a href="#">Connecting Nature</a>; <a href="#">Stad Genk</a>; <a href="#">Green4Grey</a>; the <a href="#">Flemish government</a></p>
<b>Barriers encountered and lessons learned</b>	<p>Genk was formerly seen as a Grey City (dominated by hard infrastructure), with certain areas of the city disconnected. This made community participation or sense of ownership more difficult (van de Sijpe et al., 2019). In this sense, community opinion regarding the site already used was a barrier, local residents unofficially used the space and there was a lack of interest in draining their private gardens. However, the biggest barrier was the cost of the original design. This plan sought to divert pumped water back to a pond in the nature reserve to raise the water levels in order to meet ecological goals, but it became cost-prohibitive, and mono-functional, so the plan had to change.</p> <p>The lessons learned encompass this change in the redesign of the area, since less expensive measures were taken but that met the same objectives, in addition to enhancing the ecological and social value of the area (van de Sijpe et al., 2019). Active horizontal cooperation between several departments was needed, as well as workshops with the residents of the neighbourhood to explain the project and encourage them to participate in its co-design. Schansbroek was the first area to be redeveloped in the Stiemervallei context, so the lessons learned in terms of project management, stakeholder engagement and citizen communication will be of great use to scale up in other areas of the city.</p>
<b>Case study author</b>	<p>Adina Dumitru<sup>1</sup> (<a href="mailto:adina.dumitru@udc.es">adina.dumitru@udc.es</a>), David Tomé-Lourido<sup>1</sup>, Peter Vos<sup>2</sup>, Katrien van de Sijpe<sup>2</sup>  <sup>1</sup>University of A Coruña, Spain  <sup>2</sup>City of Genk, Belgium</p>
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Figure 5-6. **Schansbroek Park** (© Green4Grey).



## 5.2 Case studies illustrating the 'story of an indicator' for some of the additional indicators

The case studies in this section are designed to illustrate the selection and use of Additional indicators from each of the 12 Challenge areas to examine a specific aspect of a given NBS. Each case study details the need for use of an Additional indicator and describes its application and the obtained results (or anticipated results).

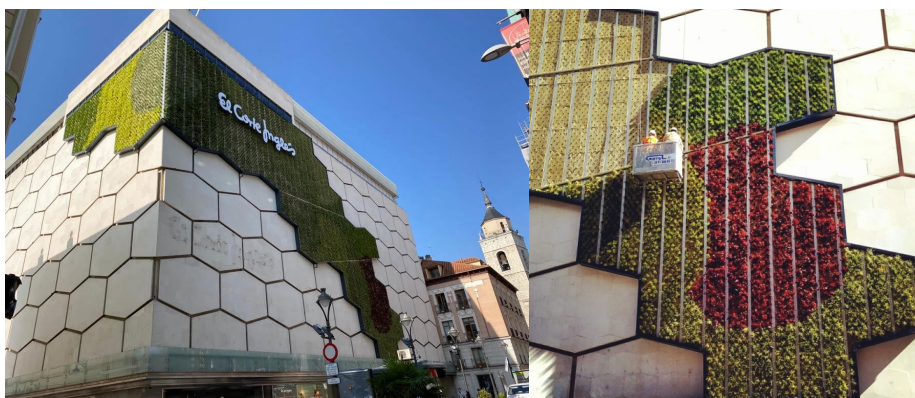
It should be noted that NBS exhibit multiple co-benefits, identification of which is of outmost importance for evaluating the wider NBS impact. Case studies for selection of Additional indicators presented herein illustrate the selection of the unique indicators. They merely serve as examples of versatility of the NBS impact assessment approach, which can be tailored to local needs and challenges.

### 5.2.1 Climate Resilience – Urban Heat Island incidence

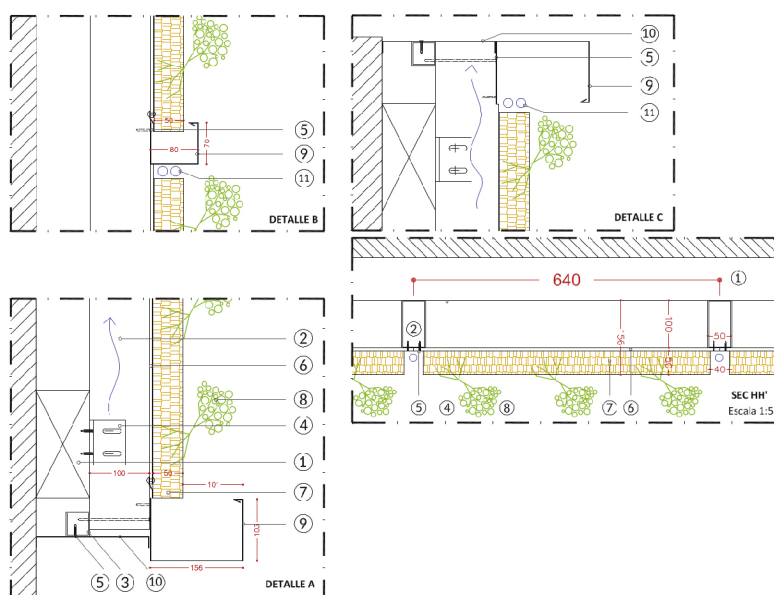
NBS name and location	Green façade Valladolid Demo Site Shopping Centre El Corte Inglés, Calle Constitución, 2. 47001 Valladolid (Spain)
<b>Brief description of NBS</b>	<p><b>Green Facade</b> is a constructive system that allows planting on a vertical façade. This NBS is built with a substructure and a waterproof panel. The substructure is affixed to the façade. The plants grow in a growing medium that is affixed to the panels. The water of the irrigation system nourishes the plants.</p> <p>This green wall was built in collaboration with a private company (<i>El Corte Inglés</i>), and has benefits for every part involved in the project: the mall, renewing the image of the facade and attracting new customers, and the city, improving the air quality, climate regulation, pollination and adding aesthetic values to a grey area in the city centre of Valladolid. This vertical garden covers an area of 350 m<sup>2</sup> and has more than 14,000 plants (Figure 5-7, Figure 5-8).</p>
<b>Additional Indicators of relevance</b>	<p>1.5 Heatwave incidence  <b>1.13 Urban Heat Island (UHI) incidence</b>  1.15 Mean or peak daytime temperature - 1.15.1 Direct measurement.</p> <p><b>6.9 Trends in emissions of NO<sub>x</sub> and SO<sub>x</sub></b>  6.10 Monetary values: value of air pollution reduction; total monetary value of urban forests including air quality, run-off mitigation, energy savings, and increase in property values.  6.11 Air quality parameters. NO<sub>x</sub> and PM.</p>
<b>Explanation for selection of</b>	In future, if this NBS is widely installed it can be used recommended indicators for climate change and Air Quality



<b>Additional Indicators</b>	challenge. Recommended indicators have a scale of measurement from district to region and they have not sensibility enough to study the impact of this NBS. Therefore, in the meantime it is needed additional indicators to assess the impact on air pollutants emission reduction with indicators such as the ones mentioned before.
<b>Description of Additional Indicator Application</b>	In this case, the main indicator for impact assessment is 1.5 and 1.15 (1.15.1) and additionally the other ones. 1.15 implies the installation of several equipment for continuous monitoring of temperature and humidity in the green façade location and reference areas.
<b>Stakeholders involved</b>	Different municipality areas (at least urbanism, environment and heritage), shopping centre company ( <i>El Corte Inglés</i> ), construction companies.
<b>Barriers encountered and lessons learned</b>	Regarding the NBS implementation, the main barriers were administrative and economic. The green façade was installed in a commercial private building in a relevant area of the city. URBAN GreenUP joined the efforts of the <i>El Corte Inglés</i> technical team, different areas of the Valladolid city council and the technical experts of the Project led by SingularGreen. After more than 1 year of discussions, it was decided to separate into two interventions: A structure to support the NBS and the vertical garden itself. The structure was attached to the existing wall and it was designed and constructed by <i>El Corte Inglés</i> . Then, Green Facade was manage with local and EU funds.
<b>Case study authors</b>	Jordi Serramia <sup>1</sup> , Hugo Riquelme <sup>1</sup> , Patricia Briega <sup>1</sup> , Alicia Villazán <sup>2</sup> , Isabel Sánchez <sup>2</sup> , Elena Sánchez <sup>2</sup> , Juan Carlos Sánchez <sup>3</sup> , Raúl Sánchez <sup>4</sup> , Jose Feroso <sup>4</sup> , Raquel Marijuan <sup>4</sup> , Silvia Gómez <sup>4</sup> , María González <sup>4</sup> , José María Sanz <sup>4</sup> , Esther San José <sup>4</sup> <sup>1</sup> SingularGreen S.L. C/ Francisco Carratalá Cernuda, 34 Bajo, 03010, Alicante, Spain <sup>2</sup> VALLADOLID City Council. Plaza Mayor 1, 47001, Valladolid, Spain <sup>3</sup> Tierra Ingeniería S.L. C/ Copenhagen, 6, 28230, Las Rozas, Spain <sup>4</sup> CARTIF Foundation. P.T. Boecillo, 205, 47151, Boecillo, Valladolid, Spain

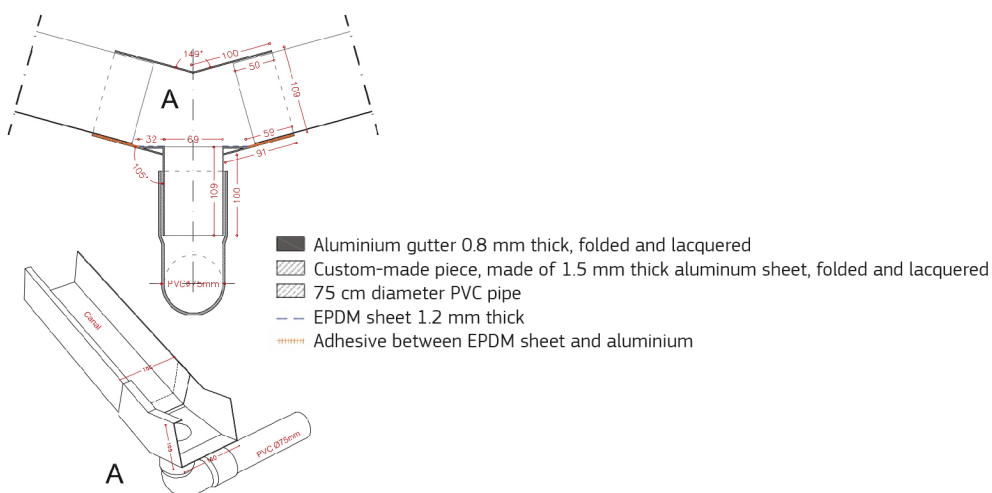


**Figure 5-7.** The green façade at El Corte Inglés, Valladolid.



#### LEGEND

- |   |   |
|---|---|
| 1- Support structure planned for vertical garden anchoring                            | 8- Vegetation selected by SingularGreen S.L.  |
| 2- Vertical garden substructure. Aluminum upright 100x50.2mm                          | 9- 1.5 thick aluminium gutter, lacquered. Color to be chosen by the Facultative Direction   |
| 3- Square section aluminum profile for anchoring the garden finishing perimeter sheet | 10- Lacquered aluminium sheet for vertical garden perimeter finishing 190x20mm. Self-tapping anchored to aluminium profile. Color to be chosen by the Facultative Direction |
| 4- Galvanized steel anchor bracket with dimensions 60x60x100.2mm                      | 11- Irrigation pipe SG-R16, self-compensating drippers 1.6l / h every 20 cm   |
| 5- Zinc steel self-tapping screw  |   |
| 6- 5mm thick foamed PVC panel screwed to uprights                                     |   |
| 7- Substrate made of rock wool panels of 80kg / m3. 50mm                              |   |



**Figure 5-8.** URBAN GreenUP Project: Green Façade construction details (© SingularGreen).

## 5.2.2 Natural and Climate Hazards – Flood risk

NBS Name and Location	Green barrier <b>Gudbrandsdalen Valley, Norway</b>
<b>Brief description of NBS</b>	<p>A receded green flood barrier located at Jorekstad in Lillehammer municipality (Figure 5-9) is proposed to reduce the risk of floods due to snow melting and extreme rainfall. The NBS consists of removing the existing flood protection along a section of the riverbank, and building a new flood barrier, using only natural and local materials, further upland of the riverbanks. This will provide space for the river during periods of flooding and improve the capacity for upstream flood levels, as well as contribute positively to the flood plain ecosystem. For more information see: <a href="https://phusicos.eu/case_study/valley-of-gudbrandsdalen-norway/">https://phusicos.eu/case_study/valley-of-gudbrandsdalen-norway/</a></p>
<b>Additional Indicators of relevance</b>	<p><b>Risk reduction:</b></p> <ul style="list-style-type: none"> <li>6.13.1 Urban /Residential Areas</li> <li>6.13.2 Productive Areas (Agriculture, Grazing, Industries)</li> <li>6.15.1 Inhabitants</li> <li>6.15.3 Other People (Workers, Tourists, Homeless)</li> <li>6.15.4 Elderly, children, disabled</li> <li>6.16.1 Population</li> <li>6.17.1 Housing</li> <li>6.17.2 Agricultural and Industrial Buildings</li> <li>6.18.1 Roads</li> <li>6.18.2 Transportation Infrastructures and Lifelines</li> <li>6.18.3 Lifelines (Water main, Sewerage, Pipeline, etc.)</li> <li>6.19.1 Buildings</li> <li>6.22 Flooded Area</li> <li>6.24 Peak Flow</li> <li>24.24 Economic Value of the Productive Activities Vulnerable to Risk (i.e. Economic Value of the Fields, Workers No.)</li> </ul> <p><b>Technical and feasibility aspects:</b></p> <ul style="list-style-type: none"> <li>14.22 Material used coherence</li> <li>24.5 Initial costs</li> <li>24.6 Maintenance costs</li> <li>24.7 Replacement costs</li> <li>24.8 Avoided costs</li> <li>24.9 Payback Period</li> </ul> <p><b>Environment and ecosystem:</b></p> <ul style="list-style-type: none"> <li>4.48 Physical parameters</li> <li>4.48 Chemical Pollution Parameters</li> <li>4.23 Water Storage Capacity Enhancement</li> <li>6.41 Total Predicted Soil Loss (RUSLE)</li> <li>10.22 Typical Vegetation Species Cover</li> <li>10.3.1 Abundance of Ecotones/Shannon Diversity</li> </ul>

	<p>10.25.1 Diversity of Functional Groups (Plant Functional Diversity)</p> <p>10.25.2 Diversity of Functional Groups (Animal Functional Diversity)</p> <p>10.7.1 Sites of Community Importance (SCI) And Special Protection Areas (SPA)</p> <p><b>Society:</b></p> <p>8.31.2 Number of Visitors in New Recreational Areas</p> <p>Different Activities Allowed in New Recreational Areas</p> <p>8.35.1 New Pedestrian, Cycling and Horse Paths</p> <p>23.2 Rate of Increase in Properties Incomes</p> <p>18.1.1 Citizen Involved</p> <p>18.1.2 Stakeholders Involved</p> <p>17.3 Public-Private Partnership Activated</p> <p>17.4 Policies Set Up to Promote NBS</p> <p>14.7 Social Active Associations</p> <p>14.17 Natural and Cultural Sites, Made Available</p> <p>14.25 Viewshed</p> <p>14.26 Scenic Sites and Landmark Created</p> <p><b>Local economy:</b></p> <p>24.18 Jobs Created in The Nature-Based Sector</p> <p>24.19 Jobs Created in The Nature-Based Solution Construction and Maintenance</p> <p>24.17 Gross Profit from Nature-Based Tourism</p> <p>24.15 Touristic Activeness Enhancing</p> <p>24.33 New Areas Made Available for Traditional Activities (Agriculture, Livestock, Fishing, ...)</p>
<b>Explanation for selection of Additional Indicators</b>	<p>The indicators tailored to this case study encompass a total of 47 indicators. The indicators are aggregated to provide information about the NBS with respect to five ambits: 1) Risk reduction, 2) Technical and feasibility aspects, 3) Environment and ecosystem, 4) Effects on the society, and 5) Effects on local economy. These five ambits form the basis of the NBS assessment framework developed in the PHUSICOS project (<a href="http://www.phusicos.eu">www.phusicos.eu</a>).</p>
<b>Description of Additional Indicator Application</b>	<p>Quantitative, risk-related indicators include Peak Flow volume, Flooded Area – calculated through hydraulic modelling – and Exposed residential and productive areas, obtained by GIS mapping. Ecosystem indicators are aimed to assess both the effects on water quality, such as the Change in physical and chemical water parameters, and water quantity, such as the Total predicted soil loss (RUSLE), or enhanced Water storage capacity. Indicators for assessing the improved value of the forested floodplain include Typical vegetation species cover, and Diversity in plant and animal functional groups. Societal-related indicators include the Number of visitors in the new recreational areas and New pedestrian/cycling paths, whilst the Number of jobs created in the nature-based sector is one of the economy-related indicators.</p>

<b>Stakeholders involved</b>	Innlandet County Administration, Lillehammer municipality, Private land owners, Local farmers' association, Norges Naturvernforbund (Friends of the Earth Norway, an environmental and nature protection NGO)
<b>Barriers encountered and lessons learned</b>	<p><b><u>Barriers encountered:</u></b></p> <p>The tendering process for procurement of goods and services is often not straightforward, there are complaints from bidders who were not selected, etc.</p> <p>Local politics and bureaucracy; revision of land use plans, local elections, etc.</p> <p>Land owners resisting use of their land, for various reasons, e.g.</p> <ul style="list-style-type: none"> <li>○ Loss of agricultural land</li> <li>○ General scepticism to NBS, or lack of knowledge</li> <li>○ Economic reasons; want land compensation, lose extra income from gravel out-take</li> </ul> <p><b><u>Lessons learned:</u></b></p> <ul style="list-style-type: none"> <li>• Plan well ahead. Getting plans through to practical implementation takes more time than one possibly could think of.</li> <li>• Bring stakeholders into the process as early as possible, if possible from scratch; co-creation and co-design of the measures establishes 'ownership' and increases enthusiasm.</li> <li>• Use their local knowledge wherever possible and show appreciation.</li> <li>• Identify potentially 'problematic' stakeholders and plan strategies to handle these.</li> <li>• If at all possible, choose public land for your NBSs.</li> <li>• Identify individuals who can be good ambassadors for the project and work closely with them.</li> <li>• Procurement can be time consuming. Be as detailed as possible in the tender documents. Complaints will lead to serious delays.</li> </ul>
<b>Case study author</b>	Vittoria Capobianco ( <a href="mailto:vittoria.capobianco@ngi.no">vittoria.capobianco@ngi.no</a> ) <i>Norwegian Geotechnical Institute, Norway</i>
<b>Reference</b>	<a href="https://phusicos.eu/case_study/valley-of-gudbrandsdalen-norway">https://phusicos.eu/case_study/valley-of-gudbrandsdalen-norway</a>

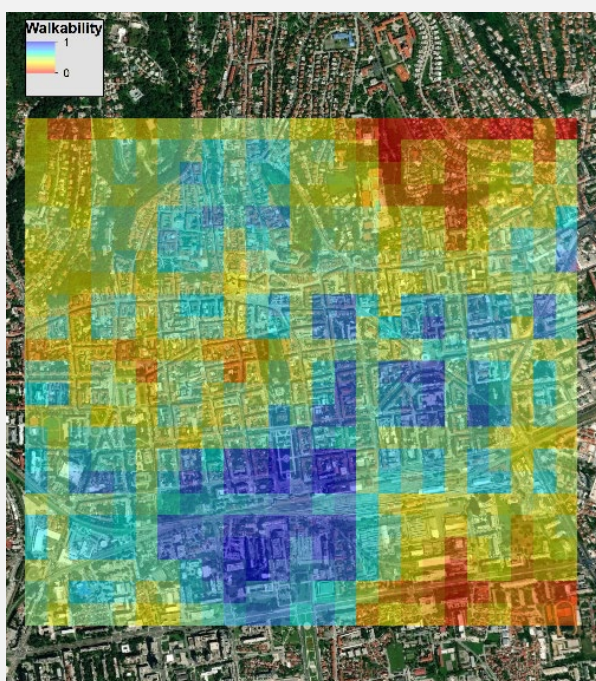




**Figure 5-9.** Aerial photo of the area with the location of the existing flood barrier and the new flood barrier (top); visualization of the area with the potential multiple actions that can be supported by the flood barrier (by Agence Ter, bottom).

### 5.2.3 Green Space Management – Walkability

NBS Name and Location	Living Lab districts <b>Turin (Italy), Zagreb (Croatia), Dortmund (Germany), Ningbo (China)</b>
<b>Brief description of NBS</b>	During the <a href="#">proGIreg</a> project, this indicator will be calculated for the Living (LL) district and for the entire city area in each Front-Runner City (FRC).
<b>Additional Indicators of relevance</b>	8.37 Walkability
<b>Explanation for selection of Additional Indicators</b>	The Walkability index express the likelihood that a particular area may be covered by walking. It provides additional information on the urban structure of a city and, in turn, individual districts. Additionally, it can be of useful in assess the effects of Land use changes (pre/post intervention)
<b>Description of Additional Indicator Application</b>	<p>The Walkability index is a GIS derived raster image, function of connectivity, accessibility and perceived pleasantness with values ranging from 0 to 1 where 1 indicates the most walkable area (e.g., a park with pedestrian lanes well connected to city hot spots like residential and working areas) and 0 indicates the least walkable area (e.g., a major urban road) (Figure 5-10).</p> <p>The calculation of the Walkability index requires the following data:</p> <ul style="list-style-type: none"> <li>○ Pop Density map</li> <li>○ Road Network</li> <li>○ Public Transit (including stops and routes)</li> <li>○ Land Use and zoning: residential, commercial and office, industrial, institutional (e.g., schools, libraries, kindergartens), green/park area, and water and wetland</li> <li>○ Digital elevation model</li> </ul>



**Figure 5-10.** Example of walkability index (city of Zagreb – preliminary results by Vincenzo Giannico, University of Bari).

**Stakeholders involved**

Civil local authorities for data collection during baseline have been involved

**Barriers encountered and lessons learned**

The walkability index is a derived metric that requires a large number of input data. This characteristic leads to two major issues: (1) data availability and (2) data harmonization across the civil local authorities involved.

To date, only two of the four FRCs (i.e., Zagreb and Dortmund) sent us the requested data. Additionally, of the received data, only the files received by the city of Zagreb were actually usable as the rest of the files were not compliant with the model request and thus were not useful. However, the problem was discussed with the local authorities of Dortmund, and they assured that the data will be provided in the correct data type within a short period of time. The city of Turin, similarly, is committed to provide the data as soon as possible.

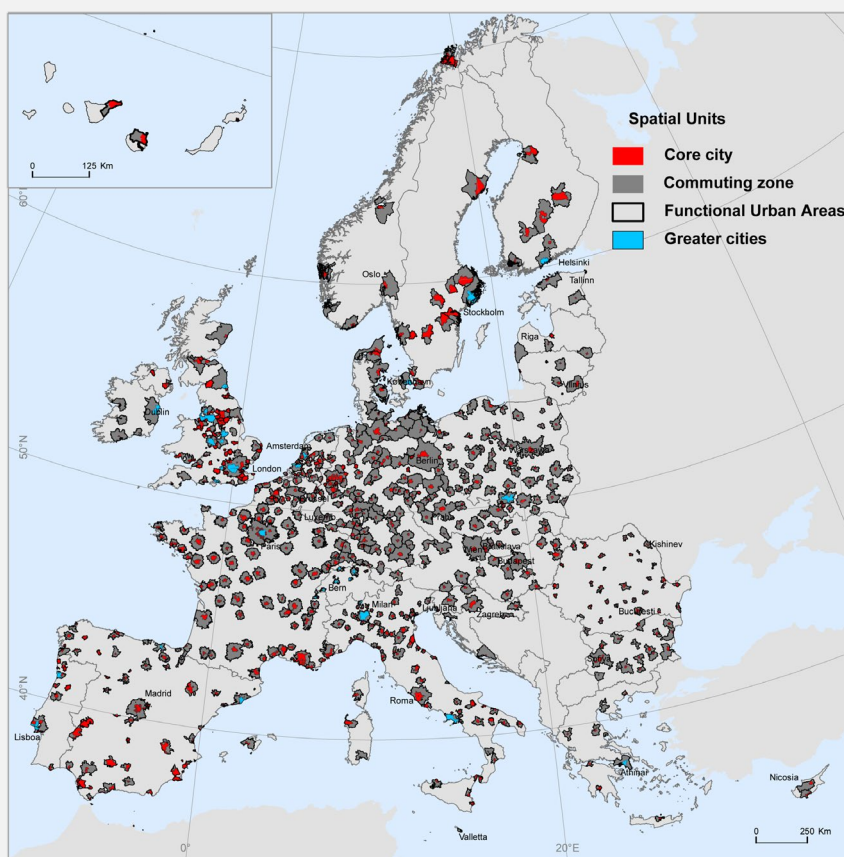
Another issue concerns the harmonization of data across cities. Given the nature of the input data involved in the calculation of the Walkability index, it has been found to be difficult to obtain data acquired in the same year across cities. For example, the Land Use map provided by city of Zagreb is from 2012 while the city of Dortmund provided a Land Use map generated in the first decade of the 2000s. Land Use maps, in particular, are usually developed on a multiyear basis by local authorities, as the changes in land use occurring yearly, especially in European cities, are



	<p>often limited. As a consequence, we will be unable to calculate a yearly walkability index, as expected initially, but rather one walkability index before the initiation of the project and, depending on the availability of the data, another walkability index at the end of the project.</p> <p>Lesson learned:</p> <ul style="list-style-type: none"> <li>○ Data collection can vary across cities and constant interaction with local authorities is needed.</li> <li>○ Given the nature of the input data, calculating a yearly walkability index is not feasible.</li> <li>○ Two Walkability index (pre/post intervention) would be calculated on the basis of the availability of the data.</li> </ul>
<b>Case study author</b>	Vincenzo Giannico ( <a href="mailto:vincenzo.giannico@uniba.it">vincenzo.giannico@uniba.it</a> ) <i>University of Bari, Italy</i>
<b>References</b>	Fan, P., Xu, L., Yue, W., and Chen, J., 'Accessibility of public urban green space in an urban periphery: The case of Shanghai', <i>Landscape and Urban Planning</i> , Vol. 165, 2017, pp. 177-192.

#### 5.2.4 Green Space Management – Annual Trend in vegetation cover

<b>NBS name and location</b>	This indicator is part of a framework applied at European level to map and assess urban ecosystems condition and ecosystem services
<b>Brief description of NBS</b>	<p>The Green Space Management – Annual Trend in vegetation cover indicator was implemented to assess changes in vegetation cover within the <i>Urban Green Spaces</i> (NBS Type 3) in 700 European Functional Urban Areas (FUAs; Figure 5-11) as part of the Mapping and Assessment of Ecosystems and their Services (MAES) initiative:</p> <p><a href="https://ec.europa.eu/environment/nature/knowledge/ecosystem_assessment/index_en.htm">https://ec.europa.eu/environment/nature/knowledge/ecosystem_assessment/index_en.htm</a></p>



**Figure 5-11.** Distribution of European functional urban areas (FUAs; (EU 28 + Norway and Switzerland) (source: Maes et al., 2020, Chapter 3.1: Urban Ecosystems).

#### Additional Indicators of relevance

At European level the following indicators have been implemented:

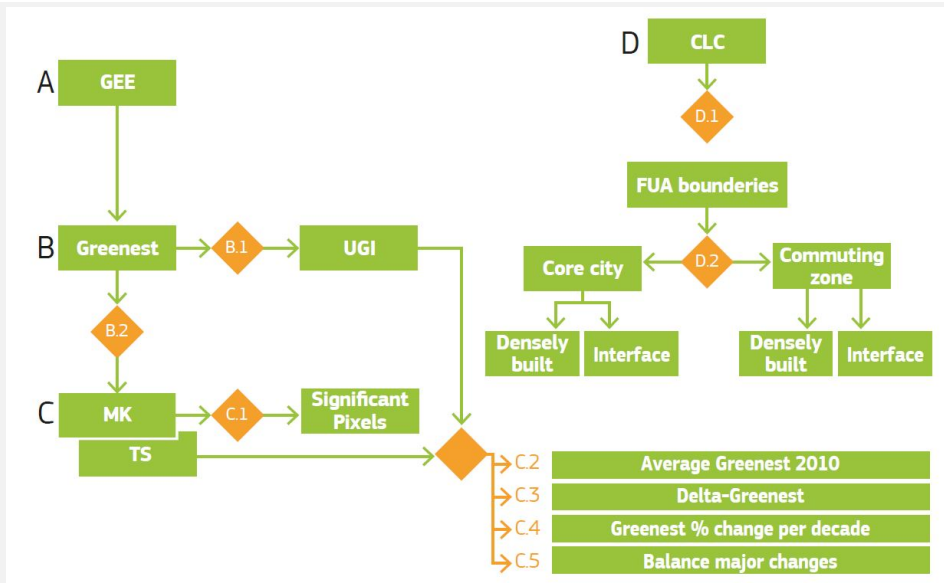
- 7.1 Green spaces Accessibility
- 7.2 Share of green urban areas
- 8.1 Ecosystem services provision (flood control, nature-based recreation, pollination)
- 8.2 Annual trend in vegetation cover by urban green infrastructure**
  - 8.31.1 ESTIMAP nature-based recreation
  - 8.38 Land composition
  - 8.39 Land use change and green space configuration
  - 8.40 Soil sealing

#### Explanation for selection of Additional Indicators

We defined Urban Green Spaces in European cities according to the EU GI Strategy (EC, 2013), as “a *strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services*” (EC, 2013). We carried out the analysis including all natural and semi-natural areas together with all private and public green spaces within the core cities and the commuting zones.

The capacity of Green Spaces to provide ecosystem services is linked to the quality and extent of vegetation cover. This indicator

	examines how and in which direction vegetation cover changed between 1996 and 2018. Trend detection in Normalized Difference Vegetation Index (NDVI) time series can help to identify and quantify recent changes in ecosystem properties.
<b>Description of Additional Indicator Application</b>	Figure 5-12 shows the steps needed to derive the indicator.



**Figure 5-12.** Suggested algorithm for the process (source: Maes et al., 2020, Chapter 3.1: Urban Ecosystems, Factsheet 3\_1\_109).

- A. Data were physically downloaded from Google earth engine (GEE)
- B. From the original maps the Urban green Infrastructure (UGI) mask was created:
  - o B.1. areas where at least once between 1996 and 2018 the highest-NDVI was greater than 0.4.
- C. The Trend analysis employed a non-parametric approach, namely the Theil-Sen regression. The slopes of the regression approach were tested for their statistical significance using the p-value of the Mann-Kendall<sup>50</sup> test for slopes (Corbane et al., 2018; Forkel et al., 2013; Jin et al., 2019; Novillo et al., 2019; Teferi, et al., 2015; Wang et al., 2018;).
  - o C.1 Only pixels where the p-value (Mann-Kendall) was less than 0.05 (95% confidence interval) have been considered to have a significant medium-term trend and used as a mask to extract all the indicators.
  - o C.2 we reported the average greenest value in 2010 as reference value.
  - o C.3 From the Theil-Sen positive or negative slope we extracted the Delta Greenest, which represent the **change direction** over the 22 years of analysis.
  - o C.4 To make the interpretation easier the annual trends were reported in terms of percentage of change per decade (using the equation proposed by Teferi et al., 2015) .
  - o C.5 The TS-Slope was reclassified in 5 classes representing key gradual to abrupt change types. They were defined using the minimum measurable change (+/-0.001)

<sup>50</sup> Mann-Kendall is a temporal trend estimator that is more robust than the least-squares slope because it is much less sensitive to outliers and skewed data (<https://clarklabs.org/terrset/>).

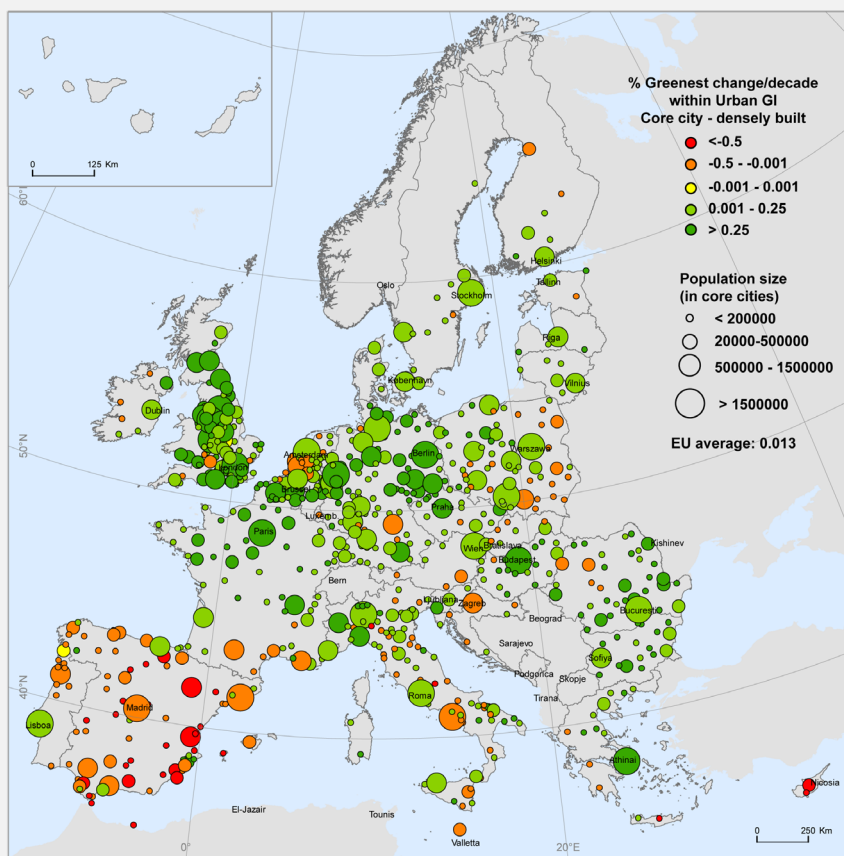
as thresholds for areas with no changes (Guan et al., 2018; Jin et al., 2019; Verbyla, 2008).

D. CLC map was reclassified using the land mosaic model in Densely built up and interface zone

- Indicators (C1-C2-C3-C4-C5) were extracted in Core cities and Commuting zone within Densely built up and interface zone **only for significant pixels of UGI.**

Spatially explicit data are available for the 700 FUA. The indicator could be used at a city level to study vegetation development within urban parks.

Figure 5-13 shows the percentage of change per decade in vegetation cover. 26% of European cities present a downward trend, meaning that there is a tendency to loose vegetation. The balance between abrupt changes (Figure 5-14) confirms the trend.



**Figure 5-13.** Trends in vegetation cover (% change/decade), within densely built areas in core cities. The pie chart shows the proportion of cities for each category (source: Maes et al., 2020, Chapter 3.1: Urban Ecosystems).

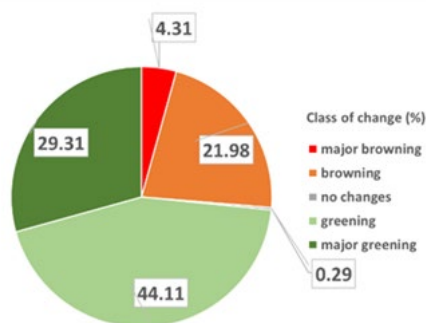
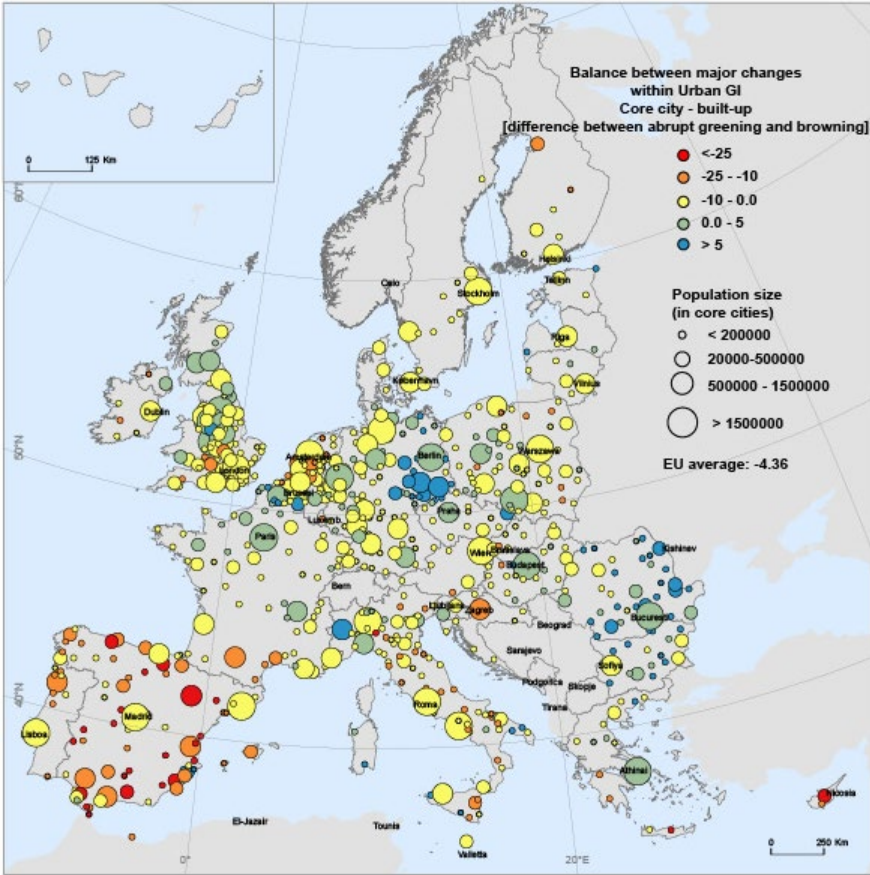
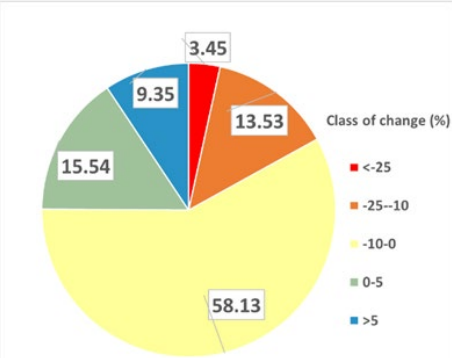


Figure 5-14 shows the difference between major greening and major browning in densely built areas of core cities. It represents a "compensation indicator", if it is positive the upward trend was higher than the downward trend and greening areas compensated the loss of green spaces. If it is negative, the land

development pattern did not include any solution to compensate the green loss. This indicator provide insights at urban/regional/national level about the compensation policies taken to avoid damages created by land take, soil sealing or climate change.



**Figure 5-14.** Balance between abrupt greening and browning changes within densely built areas in core cities. The pie chart shows the proportion of cities for each category (source: Maes et al., 2020, Chapter 3.1: Urban Ecosystems).



### Stakeholders involved

MAES represents the core activity of Action 5 – Target 2 of the EU Biodiversity strategy to 2020. The all process, started in 2013 involved EU Member States, The Commission (DG ENV, DG-JRC), The European Environmental Agency (EEA) and several other stakeholders.

Specifically a workshop, held in Brussels in June 2019, provided the opportunity for stakeholders to engage in the first EU wide ecosystem assessment.

<b>Barriers encountered and lessons learned</b>	Main barriers are linked to: expertise requested for the implementation of the indicator.
<b>Case study author</b>	Grazia Zulian ( <a href="mailto:grazia.zulian@ec.europa.eu">grazia.zulian@ec.europa.eu</a> ) <i>JRC D3 Land Resources</i>
<b>References</b>	<p>Corbane, C., Pesaresi, M., Politis, P., Florczyk, J.A., Melchiorri, M., Freire, S., Schiavina, M., Ehrlich, D., Naumann, G., and Kemper T., 'The grey-green divide: multi-temporal analysis of greenness across 10,000 urban centres derived from the Global Human Settlement Layer (GHSL)', <i>International Journal of Digital Earth</i>, 2018, pp. 101–118.</p> <p>EC, 'Green Infrastructure (GI) — Enhancing Europe's Natural Capital', COM(2013) 249 final, 2013, p. 13.</p> <p>Forkel, M., Carvalhais, N., Verbesselt, J., Mahecha, M.D., Neigh, C.S.R., and Reichstein, M., 'Trend Change detection in NDVI time series: Effects of inter-annual variability and methodology', <i>Remote Sensing</i>, Vol. 5, No 5, 2013, pp. 2113–2144.</p> <p>Jin, J., Gergel, S.E., Lu, Y., Coops, N.C., and Wang, C., 'Asian Cities are Greening While Some North American Cities are Browning: Long-Term Greenspace Patterns in 16 Cities of the Pan-Pacific Region', <i>Ecosystems</i>, 2019, pp. 383–399.</p> <p>Maes, J., Teller, A., Erhard, M., Condé, S., Vallecillo, S., Barredo, J.I., Paracchini, M.L., Abdul Malak, D., Trombetti, M., Vigiak, O., Zulian, G., Addamo, A.M., Grizzetti, B., Somma, F., Hagyo, A., Vogt, P., Polce, C., Jones, A., Marin, A.I., Ivits, E., Mauri, A., Rega, C., Czúcz, B., Ceccherini, G., Pisoni, E., Ceglar, A., De Palma, P., Cerrani, I., Meroni, M., Caudullo, G., Lugato, E., Vogt, J.V., Spinoni, J., Cammalleri, C., Bastrup-Birk, A., San Miguel, J., San Román, S., Kristensen, P., Christiansen, T., Zal, N., de Roo, A., Cardoso, A.C., Pistocchi, A., Del Barrio Alvarelllos, I., Tsiamis, K., Gervasini, E., Deriu, I., La Notte, A., Abad Viñas, R., Vizzarri, M., Camia, A., Robert, N., Kakoulaki, G., Garcia Bendito, E., Panagos, P., Ballabio, C., Scarpa, S., Montanarella, L., Orgiazzi, A., Fernandez Ugalde, O., and Santos-Martín, F., 'Mapping and Assessment of Ecosystems and their Services: An EU ecosystem assessment', EUR 30161 EN, Publications Office of the European Union, Ipsra, 2020.</p> <p>Novillo, C., Arrogante-Funes, P., and Romero-Calcerrada, R., 'Recent NDVI Trends in Mainland Spain: Land-Cover and Phytoclimatic-Type Implications', <i>ISPRS International Journal of Geo-Information</i>, Vol. 8, No 1, 2019, p. 43.</p> <p>Teferi, E., Uhlenbrook, S., and Bewket, W., 'Inter-annual and seasonal trends of vegetation condition in the Upper Blue Nile (Abay) Basin: Dual-scale time series analysis', <i>Earth System Dynamics</i>, Vol. 6, No 2, 2015, pp. 617–636.</p> <p>Wang, J., Zhou, W., Qian, Y., Li, W., and Han, L., 'Quantifying and characterizing the dynamics of urban greenspace at the patch level: A new approach using object-based image analysis', <i>Remote Sensing of Environment</i>, Vol. 204, 2018, pp. 94–108.</p>



### 5.2.5 Green Space Management - ESTIMAP nature-based recreation

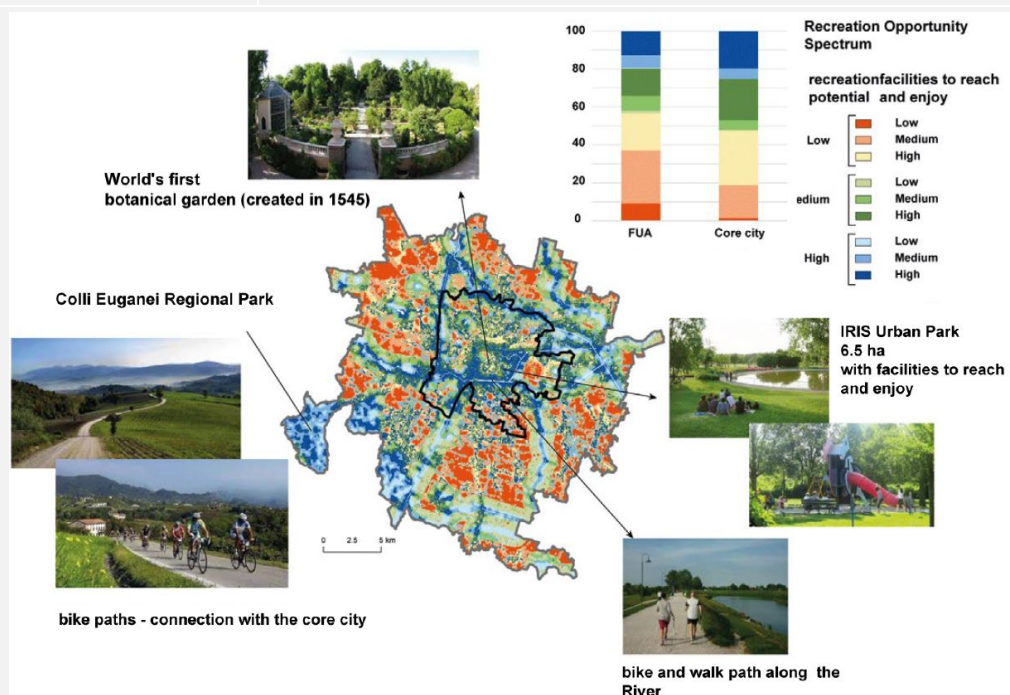
NBS name and location	This indicator is part of a framework applied at European level to map and assess urban green spaces and ecosystem services.
<b>Brief description of NBS</b>	<p>The indicator was implemented to assess the capacity of <b>urban ecosystems</b> to provide nature based recreation opportunities in 700 European Functional Urban Areas (FUAs; see Figure 5-11 in case study 5.2.4 Green Space Management – Annual Trend in vegetation cover). This work was part of the EnRoute project:  <a href="https://oppla.eu/groups/enroute">https://oppla.eu/groups/enroute</a>  <a href="https://publications.jrc.ec.europa.eu/repository/handle/JRC115375">https://publications.jrc.ec.europa.eu/repository/handle/JRC115375</a></p> <p>Several cities in <b>EnRoute</b> applied the model at a local scale in close collaboration with the municipalities:  Poznan: <a href="https://oppla.eu/casestudy/19236">https://oppla.eu/casestudy/19236</a>  Tento: <a href="https://oppla.eu/casestudy/19228">https://oppla.eu/casestudy/19228</a>  Oslo: <a href="https://oppla.eu/casestudy/19231">https://oppla.eu/casestudy/19231</a></p>
<b>Additional Indicators of relevance</b>	<p>At European level the following indicators have been implemented:</p> <ul style="list-style-type: none"> <li>7.1 Green spaces Accessibility</li> <li>7.2 Share of green urban areas</li> <li>8.1 Ecosystem services provision (flood control, nature-based recreation, pollination)</li> <li>8.2 Annual trend in vegetation cover in urban green infrastructure</li> <li>8.31.1 <b>ESTIMAP nature-based recreation</b></li> <li>8.38 Land composition</li> <li>8.39 Land use change and green space configuration</li> <li>8.40 Soil sealing</li> </ul> <p>Spatially explicit data are available for the 700 FUA.</p>
<b>Explanation for selection of Additional Indicators</b>	<p>Nature based recreation or “Physical and experiential interactions with natural environment” (CICES, <a href="https://cices.eu/">https://cices.eu/</a>) includes a wide list of possible experience and activities such as biking; boating; climbing; hiking; horseback riding, walk the dog in a nice area; enjoy a local play ground ; find an urban park nearby.</p> <p>ESTIMAP nature-based recreation was developed to map the combination of recreation opportunities available in a given location. The original model (Liquete et al., 2016; Paracchini et al., 2014; Vallecillo et al., 2019; Zulian et al., 2013), up to now applied at European scale, was adapted to fit the urban setting. In previous applications the approach was used in urban context (Zulian et al., 2017), but focused only on specific local applications and cities, such as in Barcelona (Baró et al., 2016) or Trento (Cortinovis, Zulian and Geneletti, 2018).</p> <p>Urban ESTIMAP -recreation consists of three basic sections:</p> <ul style="list-style-type: none"> <li>o The Recreation Potential (RP), which estimates the potential capacity of ecosystems to support nature-based recreational activities. It is based on land suitability for recreation and a combination of the natural features that influence recreational opportunity provision (e.g., proximity to lakes; viewpoints of geological or geomorphological interest ...)</li> </ul>

- o The Opportunity map (OS) expresses the presence of facilities to enjoy and reach areas with potential opportunities.
- o The Recreation Opportunity Spectrum map (ROS) combines the Opportunity map (OS) and the Recreation Potential (RP).

From a modelling point of view the whole approach is based on 'Advanced multiple layer Look-up Tables' (LUT) and "proximity" concepts. Advanced LUT consist of a combination of elements, scored according to their suitability to provide recreation opportunities. In this application the scores for each input were generated from either the literature or expert input (Schröter et al., 2015). The final outcomes are based on cross tabulation and spatial composition derived from the overlay of different thematic maps (Zulian et al., 2017).

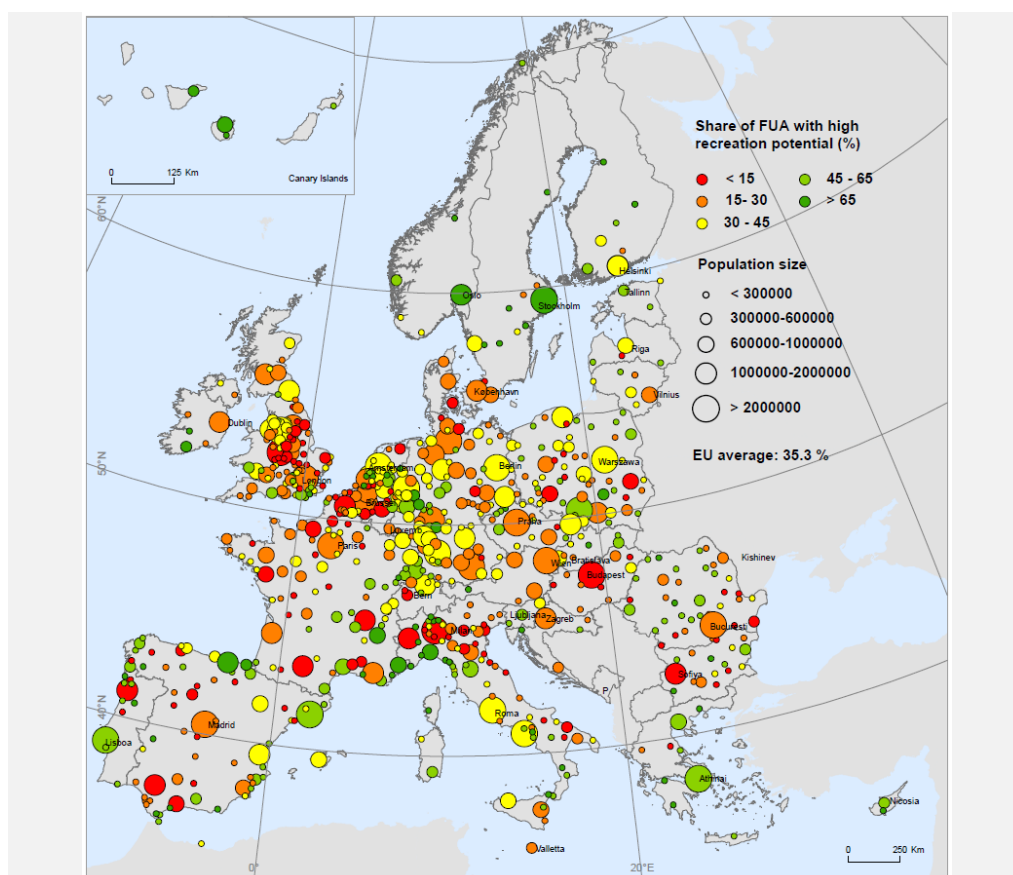
Figure 5-16 shows an example of ROS map, applied to the FUA of Padova (Italy).

Figure 5-17 shows the share of areas with high recreation potential within European FUAs.



**Figure 5-15.** The approach for mapping recreation opportunities in cities explained for the functional urban area of Padova, Italy (source: Maes et al., 2019, Box 2).





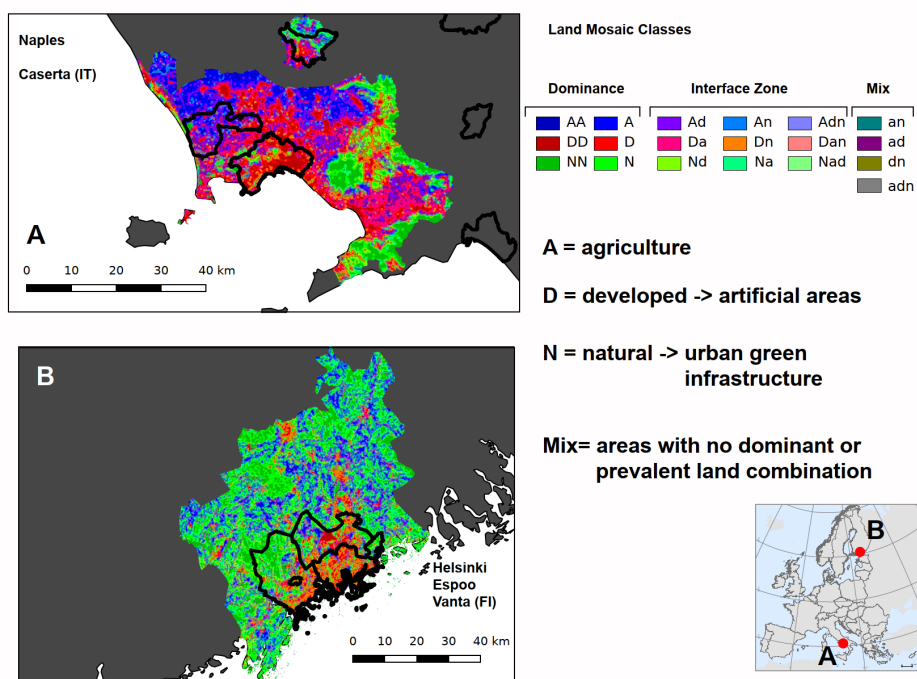
**Figure 5-16.** Surface area with high recreation potential in European functional urban areas (FUAs) (source: Maes et al., 2019).

<b>Stakeholders involved</b>	EnRoute is a project of the European Commission in the framework of the EU Biodiversity Strategy and the Green Infrastructure Strategy. EnRoute provides scientific knowledge of how urban ecosystems can support urban planning at different stages of policy and for various spatial scales and how to help policy-making for sustainable cities. A key pillar of the project is science-policy interface. Local stakeholders were involved in all the activities carried on at a local scale.
<b>Barriers encountered and lessons learned</b>	Main barriers are linked to: expertise requested for the implementation of the indicator.
<b>Case study author</b>	Grazia Zulian <sup>1</sup> , Georgia Kakoulaki <sup>2</sup> <sup>1</sup> JRC D3 Land Resources <sup>2</sup> JRC C2
<b>References</b>	Cortinovis, C., Zulian, G., and Geneletti, D., 'Assessing Nature-Based Recreation to Support Urban Green Infrastructure Planning in Trento (Italy)', <i>Land</i> , Vol. 7, No 4, 2018, p. 112. Liquete, C., Piroddi, C., Macías, D., Druon, J.N., and Zulian, G., 'Ecosystem services sustainability in the Mediterranean Sea: Assessment of status and trends using multiple modelling approaches', <i>Scientific Reports</i> , Vol. 6, 2016, Art. No 34162.

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- Schröter, M., Remme, R.P., Sumarga, E., Barton, D.N. and Hein, L., 'Lessons learned for spatial modelling of ecosystem services in support of ecosystem accounting', *Ecosystem Services*, Vol. 13, 2015, pp. 64–69.
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- Zulian, G., Paracchini, M.L., Maes, J., and Liqueste, C., 'ESTIMAP: Ecosystem services mapping at European scale', *Publications Office of the European Union*, Luxembourg, 2013.
- Zulian, G., Stange, E., Woods, H., Carvalho, L., Dick, J., Andrews, C., Baró, F., Vizciano, P., Barton, D.N., Nowel, M., Rusch, G.M., Aurunes, P., Fernandes, J., Ferraz, D., Ferreira dos Santos, R., Aszalós, R., Arany, I., Czúcz, B., Priess, J.A., Hoyer, C., Bürger-Patricio, G., Lapola, D., Mederly, P., Halabuk, A., Bezak, P., Kopperionen, L., and Viinikka, A., 'Practical application of spatial ecosystem service models to aid decision support', *Ecosystem Services*, Vol. 29 C, 2018, pp. 465-480.

### 5.2.6 Green Space Management – Land composition

NBS name and location	This indicator is part of a framework applied at European level to map and assess urban ecosystems condition and ecosystem services
<b>Brief description of NBS</b>	<p>The indicator was implemented to assess <b>Land composition</b> in 700 European Functional Urban Areas (FUAs; see Figure 5-11 in case study 5.2.4 Green Space Management – Annual Trend in vegetation cover).</p> <p>This work was part of the <b>EnRoute</b> project and the MAES initiative.  <a href="https://oppla.eu/groups/enroute">https://oppla.eu/groups/enroute</a>  <a href="https://publications.jrc.ec.europa.eu/repository/handle/JRC115375">https://publications.jrc.ec.europa.eu/repository/handle/JRC115375</a></p> <p><b>Mapping and Assessment of Ecosystems and their Services – MAES:</b>  <a href="https://ec.europa.eu/environment/nature/knowledge/ecosystem_assessment/index_en.htm">https://ec.europa.eu/environment/nature/knowledge/ecosystem_assessment/index_en.htm</a></p>
<b>Additional Indicators of relevance</b>	<p>At European level the following indicators have been implemented:</p> <ul style="list-style-type: none"> <li>7.1 Green spaces Accessibility</li> <li>7.2 Share of green urban areas</li> <li>8.1 Ecosystem services provision (flood control, nature-based recreation, pollination)</li> <li>8.2 Annual trend in vegetation cover in urban green infrastructure</li> <li>8.31.1 ESTIMAP nature-based recreation</li> <li><b>8.38 Land composition</b></li> <li>8.39 Land use change and green space configuration</li> <li>8.40 Soil sealing</li> </ul>
<b>Explanation for selection of Additional Indicators</b>	<p>Land composition is a measure of the spatial distribution of elements or components of a landscape. It is used to consider the co-occurrence of land types within each FUA. It represents the arrangements of ecosystem types within and around cities (Figure 5-17).</p> <p>To quantify land composition we use the Landscape Mosaic (LM), model available in Guidos tool box <a href="https://forest.jrc.ec.europa.eu/en/activities/lpa/gtb/">https://forest.jrc.ec.europa.eu/en/activities/lpa/gtb/</a> (Vogt and Riitters, 2017).</p> <p>This indicator is useful to describe the context where NBS are deployed.</p>



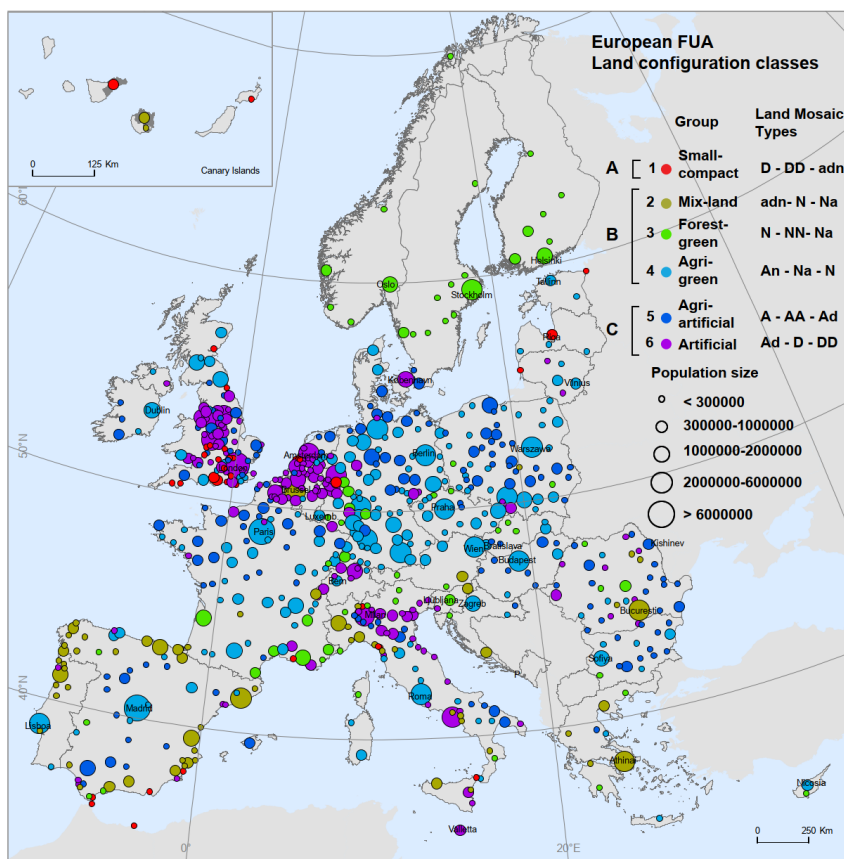
**Figure 5-17.** Land Mosaic maps in Helsinki (FI) and Naples (IT). A = Agriculture; D = Developed; N = natural; Mix = mixed presence of all land classes (source: Maes et al., 2019).

#### Description of Additional Indicator Application

Spatially explicit data are available for the 700 FUA.

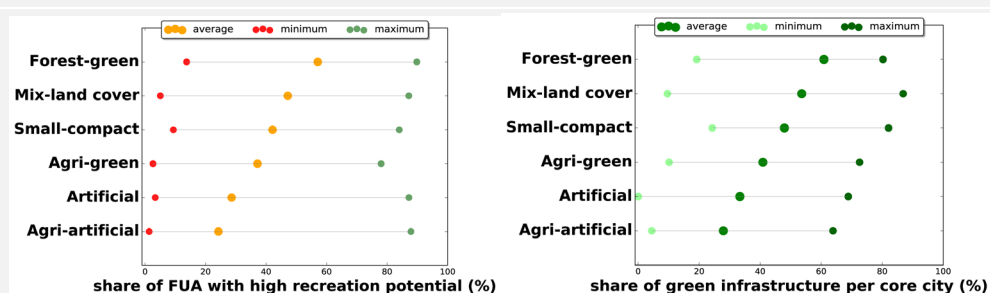
In **EnRoute** the indicator was applied to explore the capacity of urban ecosystems to provide Ecosystem services city types based on land composition and population density. Urban Atlas (<https://land.copernicus.eu/local/urban-atlas>) was used as land cover dataset.

Figure 5-18. shows EU FUA classified with reference to land composition, population density and size.



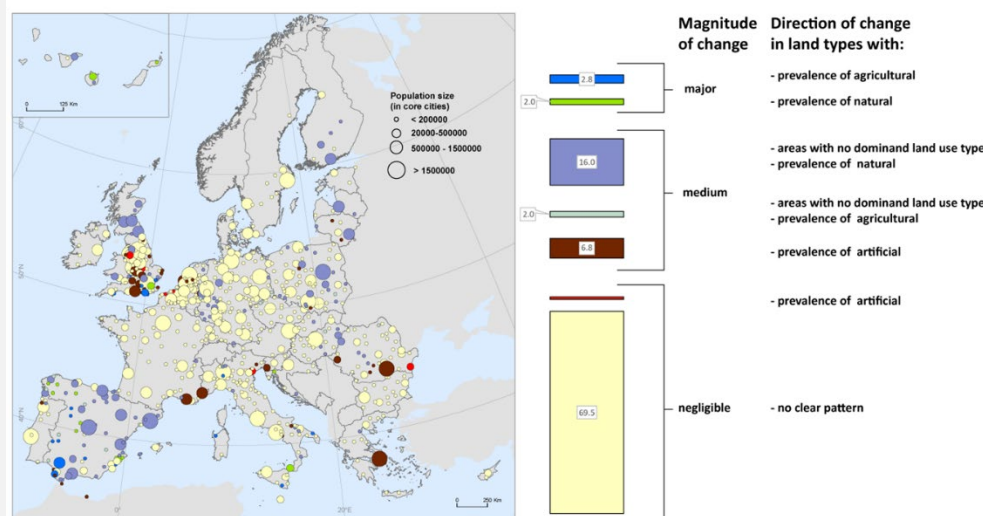
**Figure 5-18.** Spatial distribution of European functional urban areas (FUAs) classified by land composition, size and population density. The map includes FUAs in Norway and Switzerland (source: Maes et al., 2019).

Figure 5-19 shows the behaviour of two indicators (8.31.1 ESTIMAP nature based recreation and 7.2 share of urban green) with respect to the typology of cities. The indicators exhibit a high variability in average per city type as well as a high variability in the range of values. This is especially evident for the share of green spaces in core cities.



**Figure 5-19.** Average and range of the share of FUA with high recreation potential and share of green spaces per core city (source: Maes et al., 2019).

In **MAES** the indicator was applied to analyse the changes in land composition (Figure 5-20). Corine land Cover (<https://land.copernicus.eu/pan-european/corine-land-cover>) was used as land cover dataset.



**Figure 5-20.** FUAs classified in terms of magnitude and direction of change between 2000 and 2018. (source: Maes et al., 2020, Chapter 3.1: Urban Ecosystems; Factsheet 3.1.107).

#### Stakeholders involved

**EnRoute** is a project of the European Commission in the framework of the EU Biodiversity Strategy and the Green Infrastructure Strategy. EnRoute provides scientific knowledge of how urban ecosystems can support urban planning at different stages of policy and for various spatial scales and how to help policy-making for sustainable cities. A key pillar of the project is science-policy interface. Local stakeholders were involved in all the activities carried on at a local scale.

**MAES** represents the core activity of Action 5 – Target 2 of the EU Biodiversity strategy to 2020. The all process, started in 2013 involved EU Member States, The Commission (DG ENV, DG-JRC), The European Environmental Agency (EEA) and several other stakeholders.

Specifically, a workshop, held in Brussels in June 2019 provided the opportunity for stakeholders to engage in the first EU wide ecosystem assessment.

#### Barriers encountered and lessons learned

Main barriers are linked to: expertise requested for the implementation of the indicators.

#### Case study author

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JRC D3 Land Resources

#### References

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### 5.2.7 Biodiversity Enhancement – Number of conservation priority species

NBS Name and Location	Growchapel and Bellahouston Open Spaces sites Glasgow, UK
<b>Brief description of NBS</b>	<p>As part of Glasgow City Council's Open Space Strategy, they are rolling out a programme of nature-based solutions to provide targeted multifunctionality to underused open spaces across the city. The programme empowers NGOs and community groups to utilise local spaces and deliver permanent and meanwhile uses on them including the development of nature-based solutions. Interventions comprise anything from art installations, to pocket parks and urban grow-your-own spaces (Figure 5-21). Multifunctionality is at the heart of the design and Connecting Nature is supporting the out-scaling of the programme through greater focus on a nature-based solution approach, more support for NGOs and community groups to deliver sustainable stewardship plans, and a spatial dataset of ecosystem service needs across the city to support decision-making in relation to the design of the underused spaces.</p> <p><a href="https://connectingnature.eu/glasgow">https://connectingnature.eu/glasgow</a>  <a href="https://connectingnature.eu/oppla-case-study/19384">https://connectingnature.eu/oppla-case-study/19384</a></p>
<b>Additional Indicators of relevance</b>	<p>10.16 Number of conservation priority species  7.1 Greenspace accessibility  9.1 Greenspace connectivity</p>
<b>Explanation for selection of Additional Indicators</b>	<p>Whilst biodiversity net-gain is a target of Glasgow City Council's Open Space Strategy, these projects are typically delivered in small spaces and do not have the budgets to cover comprehensive biodiversity evaluations (e.g., Recommended biodiversity indicators like species diversity and functional connectivity). As such, a more targeted biodiversity indicator was needed. Evaluation of priority species associated with the spaces was seen as a win-win for the council as, it represented a more focused evaluation methodology, and it aligned more closely with strategic objectives of the local authority and existing monitoring programmes.</p>



<b>Description of Additional Indicator Application</b>	Before and after priority species evaluation would be carried out to assess any impact of the implemented nature-based solution. This would comprise a combination of local record searches and direct site evaluation.
<b>Stakeholders involved</b>	This evaluation would be carried out in collaboration with other monitoring schemes in the city (e.g., RSPB sparrow monitoring) and with other departments in within the council (e.g., biodiversity team).
<b>Barriers encountered and lessons learned</b>	Establishing contacts with appropriate departments and organisations was a challenge. Also identifying necessary expertise to carry out surveys.
<b>Case study author</b>	Stuart Connop ( <a href="mailto:s.p.connop@uel.ac.uk">s.p.connop@uel.ac.uk</a> ) <i>University of East London, UK</i>
<b>References</b>	Connecting Nature Environmental Indicators review: <a href="https://connectingnature.eu/nature-based-solution-evaluation-indicators-environmental-indicators-review">https://connectingnature.eu/nature-based-solution-evaluation-indicators-environmental-indicators-review</a>



**Figure 5-21.** Glasgow meanwhile space conversion providing a temporary grow-your-own space for the local community (© Glasgow City Council).

5.2.8 Air Quality – Trends in NOx and SOx emissions

NBS name and location	Urban garden biofilter for air pollution <b>Underground car park in Portugalete Square</b> <b>Plaza de la Libertad, 5, 47002 Valladolid (Spain)</b>
Brief description of NBS	<p><b>Urban Garden Biofilter</b> is an air filter framed in an urban garden for the emissions of <b>underground car parks or other stationary sources</b> of pollutant compounds in urban environments. This NBS has been firstly prototyped for URBAN GreenUP Project (GA nº 730426).</p> <p>The NBS is composed of three main elements, the extractor system to extract the polluted air from underground car park, the plenum section to distribute the air under the Biofilter and the Biofilter itself to clean the air and metabolize pollutants (Figure 5-22).</p> <p>It is composed by several layers for support, pollutants absorption and protection and finally is cover by vegetation. The absorption/capture of air pollutants is made by the different layers and the metabolisation of these pollutants is made by the soil microbiota and the vegetation.</p> <p>This NBS has been developed by CARTIF in a previous research project. Project results show that it can be captured most of NO<sub>x</sub> and PM (&gt;90%) from indoor air (pollutants concentration 0.5-1 ppm).</p> <p>This NBS can be adapted to existing car parks or tunnels or included in the design of new infrastructures. It can be created a new line for indoor air extraction and conduct it to the plenum zone. Then, the air will be cleaned by passing thought the biofilter materials. Due to the specific design of the biofilter layers, pressure drop of the filter is very low and simple extractor fan is used.</p>
Additional Indicators of relevance	6.9 Trends in emissions NO <sub>x</sub> and SO <sub>x</sub>

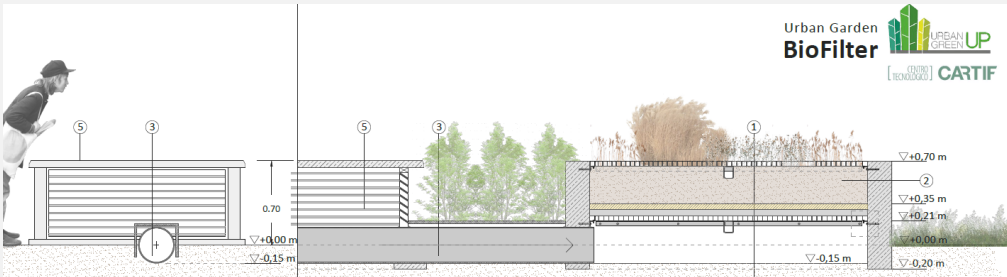


Figure 5-22. URBAN GreenUP Project: Biofilter cross section (© CARTIF).

	<p>6.10 Monetary values: value of air pollution reduction; total monetary value of urban forests including air quality, run-off mitigation, energy savings, and increase in property values.</p> <p><b>6.11 Air quality parameters. NO<sub>x</sub> and PM.</b></p> <p>6.13 Concentration of particulate matter (PM<sub>2.5</sub> and PM<sub>10</sub>) at respiration height along roadways and streets.</p>
<b>Explanation for selection of Additional Indicators</b>	<p>In future, if this NBS is widely installed it can be used recommended indicators for Air Quality challenge. Recommended indicators have a scale of measurement from district to region and they have not sensibility enough to study the impact of this NBS. Therefore, in the meantime it is needed additional indicators to assess the impact on air pollutants emission reduction with indicators such as the ones mentioned before.</p>
<b>Description of Additional Indicator Application</b>	<p>In this case, the main indicator for impact assessment is 6.11 and additionally the other ones. 6.11 implies the installation of three equipment for continuous monitoring of NO<sub>2</sub>, O<sub>3</sub> and PM (inside of the car park, next to the biofilter and separated from the biofilter but in the same square or street).</p> <p>This indicator is completed with the other in order to value and compare biofilter impact with other NBS such as tree or bush lines.</p>
<b>Stakeholders involved</b>	<p>Different municipality areas (at least urbanism, environment and heritage), car park property, construction companies</p>
<b>Barriers encountered and lessons learned</b>	<p>The main difficult aspect is found in the design and project phase for the implementation of this NBS. Impact assessment can be carried out by using one or several of the indicators depending on the budget or monitoring tool available.</p> <p>Indicator 6.11 is highly recommended and monitoring locations should be done by experts for the first studies because this is an innovative solution. The implementation of this NBS is still ongoing so no experience has been collected from the monitoring. However, when ongoing pilot studies and field analysis finish, the assessment framework can be made simpler by using indicators such as 6.9 or 6.13.</p>
<b>Case study authors</b>	<p>Raúl Sánchez<sup>1</sup>, Jose Feroso<sup>1</sup>, Francisco Verdugo<sup>1</sup>, Raquel Marijuan<sup>1</sup>, Silvia Gómez, María González<sup>1</sup>, José María Sanz<sup>1</sup>, Esther San José<sup>1</sup>, Alicia Villazán<sup>2</sup>, Isabel Sánchez<sup>2</sup>, Elena Sánchez<sup>2</sup>, Natividad Sanz<sup>3</sup>, José Antonio Pérez<sup>4</sup>, Laura Crespo<sup>5</sup></p> <p><sup>1</sup>CARTIF Foundation. P.T. Boecillo, 205, 47151, Boecillo, Valladolid, Spain</p> <p><sup>2</sup>VALLADOLID City Council. Plaza Mayor 1, 47001, Valladolid, Spain</p> <p><sup>3</sup>ISOLUX CORSAN aparcamientos. Plaza Portugaleta, s/n, 47002 Valladolid, Spain.</p> <p><sup>4</sup>CONYTRAIR. Ctra. Cabezón, 6, 47155 Santovenia de Pisuergra, Valladolid.</p> <p><sup>5</sup>LAURA CRESPO ARCHITECT, Valladolid, Spain</p>

### 5.2.9 Knowledge and Social Capacity Building for Sustainable Urban Transformation – Connectedness to nature

NBS Name and Location	Living Lab districts <b>In the cities of Turin (Italy), Zagreb (Croatia) and Dortmund (Germany)</b>
<b>Brief description of NBS</b>	During the proGireg project ( <a href="https://progireg.eu/">https://progireg.eu/</a> ), this indicator will be assessed on the general population in the Living (LL) district and 300 in a different, comparable city district ("control district") in each European Front-Runner City (FRC).
<b>Additional Indicators of relevance</b>	<b>16.3 Mindfulness/ Connectedness to nature</b> 22.13 Perceived restorativeness of NBS/ green space
<b>Explanation for selection of Additional Indicators</b>	This indicator is widely used in social sciences since it provides a reliable assessment of the relationship between human being and the natural environment
<b>Description of Additional Indicator Application</b>	Connectedness with nature is defined as the sense of oneness to nature. This indicator is part of the socio-cultural inclusiveness evaluation as a component of a survey for the assessment health, social and economic benefits of NBSs. The "Connectedness to nature scale" (CNS; Mayer, 2004), a validated tool for assessing this indicator, will involve 300 persons in each district during two time points, i.e., pre- and post- NBS implementations (after three years). The scale includes 14 items with a 5-point Likert scale ranging from "Strongly disagree" to "Strongly agree".
<b>Stakeholders involved</b>	Civil local authorities and university students for data collection during baseline have been involved
<b>Barriers encountered and lessons learned</b>	<p>The three European FRCs followed a standardized procedure for recruitment and data collection, in accordance with the proGireg scientific WP. Despite the support of the scientific WP through informal exchange of information and formal meetings in order to implement strategies to reach the target number of completed questionnaires, the final outcome differed within the FRCs. The city of Dortmund has collected 140 interviews (48 in the LL and 92 in the control district), the city of Turin has collected 398 interviews (221 in the LL and 177 in the control district). Only the city of Zagreb managed to reach and even exceeded the determined target number of interviews, previously set at 600 (302 from the LL and 313 from the control district).</p> <p>All cities sent a first information letter to the population in order to invite to participate in our research. In Turin, the invitation letters were sent a second time. As expected, the response rate was very variable between cities and was between 15% and 40%. The information reported by the cities provides useful insights for future planning of questionnaires, of which Connectedness with</p>

	<p>nature scale is part. Participants from each FRC complained about some aspects of the general questionnaire such as the excessive length and the presence of uncomfortable questions. No complaints were specifically addressed to the Connectedness with nature scale.</p> <p>Lessons learned regards the strategies that each FRC implemented to overcome the barriers encountered in reaching the target number of participants, briefly summarized below.</p> <ul style="list-style-type: none"> <li>- Application of a door-to-door technique to directly approach the target population</li> <li>- Organization of public events in the neighbourhoods concerned in order to increase the sample size.</li> <li>- Second sending of invitation letters following the unsatisfactory response of the population to the first sending.</li> <li>- Possibility of hiring specialized personnel to conduct the survey.</li> </ul>
<b>Case study author</b>	<p>Giuseppina Spano (<a href="mailto:giuseppina.spano@uniba.it">giuseppina.spano@uniba.it</a>) University of Bari, Italy</p>
<b>References</b>	<p>Mayer, F., 'The connectedness to nature scale: A measure of individuals' feeling in community with nature', <i>Journal of Environmental Psychology</i>, Vol. 24, 2004, pp. 503-515.</p>

#### 5.2.10 Social Justice and Social Cohesion – Perceived social support

NBS Name and Location	<p>Living Lab districts</p> <p><b>In the cities of Turin (Italy), Zagreb (Croatia) and Dortmund (Germany)</b></p>
<b>Brief description of NBS</b>	<p>During the proGireg project (<a href="https://progireg.eu/">https://progireg.eu/</a>), this indicator will be assessed on the general population in the Living (LL) district and 300 in a different, comparable city district ("control district") in each European Front-Runner City (FRC).</p>
<b>Additional Indicators of relevance</b>	<p>20.4.1 Perception of socially supportive network</p> <p><b>20.4.2 Perceived social support</b></p>
<b>Explanation for selection of Additional Indicators</b>	<p>Empirical evidences showed that supportive social groups and effective and helpful social networks are associated with a good mental and physical health. This indicator is measured in the neighbour-hood context since a perception of high social support fosters social inclusion and justice.</p>

<b>Description of Additional Indicator Application</b>	Perceived social support is defined as the perception of various ways in which individuals aid others. This indicator is obtained using an 8-point scale on general social support and a 6-point scale on social support in the neighbourhood.
<b>Stakeholders involved</b>	Civil local authorities and university students for data collection during baseline have been involved
<b>Barriers encountered and lessons learned</b>	<p>The three European FRCs followed a standardized procedure for recruitment and data collection, in accordance with the proGireg scientific WP. Despite the support of the scientific WP through informal exchange of information and formal meetings in order to implement strategies to reach the target number of completed questionnaires, the final outcome differed within the FRCs. The city of Dortmund has collected 140 interviews (48 in the LL and 92 in the control district), the city of Turin has collected 398 interviews (221 in the LL and 177 in the control district). Only the city of Zagreb managed to reach and even exceeded the determined target number of interviews, previously set at 600 (302 from the LL and 313 from the control district).</p> <p>All cities sent a first information letter to the population in order to invite to participate in our research. In Turin, the invitation letters were sent a second time. As expected, the response rate was very variable between cities and was between 15% and 40%. The information reported by the cities provides useful insights for future planning of questionnaires, of which the scale on perceived social support is part. Participants from each FRC complained about some aspects of the general questionnaire such as the excessive length and the presence of uncomfortable questions. No complaints were specifically addressed to the perceived social support scale.</p> <p>Lessons learned regards the strategies that each FRC implemented to overcome the barriers encountered in reaching the target number of participants, briefly summarized below.</p> <ul style="list-style-type: none"> <li>- Application of a door-to-door technique to directly approach the target population</li> <li>- Organization of public events in the neighbourhoods concerned in order to increase the sample size.</li> <li>- Second sending of invitation letters following the unsatisfactory response of the population to the first sending.</li> <li>- Possibility of hiring specialized personnel to conduct the survey.</li> </ul>
<b>Case study author</b>	Giuseppina Spano ( <a href="mailto:giuseppina.spano@uniba.it">giuseppina.spano@uniba.it</a> ) University of Bari, Italy
<b>References</b>	Pearson, J.E., 'The definition and measurement of social support', <i>Journal of Counseling and Development</i> , Vol. 64, 1986, p. 390-395.



### 5.2.11 Health and Wellbeing – Prevalence, incidence, and morbidity of chronic stress

NBS Name and Location	Stalled Spaces Glasgow, Scotland
<b>Brief description of NBS</b>	<p><b>Description</b></p> <p>Stalled Spaces (Figure 5-23) is a programme launched by <a href="#">Glasgow City Council</a> to support community groups and local organisations across the city develop temporary projects on stalled sites or under-utilised open spaces. In particular, the Stalled Spaces programme gives local organizations the opportunity to temporarily use a plot of these spaces in a way which will bring multiple benefits to the local communities.</p> <p>Projects supported by the programme deliver a range of initiatives based on the needs of the community. It means that community stakeholders decide how to use these spaces and how to adapt them to cover their needs. Examples of these initiatives are: growing spaces, pop-up gardens, wildlife areas, urban gyms or natural play spaces, temporary art in the form of pop-up sculptures, and spaces for events or exhibitions.</p> <p><b>Relevance</b></p> <p>The programme was started in 2011 and only in its first five years has helped deliver over 100 projects that have successfully brought over 25 ha of vacant, underutilised or stalled sites under temporary community use.</p>
<b>Additional Indicators of relevance</b>	<p><b>22.22 Prevalence, incidence, morbidity of chronic stress</b></p> <p><b>Short name:</b> Chronic stress</p> <p><b>Definition:</b> Within <a href="#">Connecting Nature</a>, stress is defined as the process by which an individual responds psychologically, physiologically, and often with behaviours, to a situation that challenges or threatens well-being (Baum et al., 1985 as cited in Ulrich et al., 1991, p. 202). The psychological component includes cognitive appraisal of the situation, emotions such as fear, anger, and sadness, and coping responses (Ulrich et al., 1991).</p>
<b>Explanation for selection of Additional Indicators</b>	<ol style="list-style-type: none"> <li><b>Theoretical pertinence.</b> Two theoretical frameworks that establish an association between exposition to / engagement with nature and stress alleviation have been identified: Attention Restoration Theory (ART) (Kaplan, 1995) and Stress Recovery Theory (SRT) (Ulrich et al., 1991).</li> <li><b>Impact of the health problem.</b> Chronic stress associated to modern urban lifestyles is a serious health problem with an increasing incidence around the world. Moreover, psychological stress is considered as a significant factor in the onset, course and exacerbation of other chronic diseases (depression, cardiovascular diseases...) and it has been related to the higher overall mortality (Cohen et al., 2007; Hammen, 2005; Klein et al., 2016).</li> </ol>

	<p><b>3. Appropriateness of the NBS characteristics.</b> The multiple initiatives launched in the frame of the Stalled Spaces Programme over the last decade have not only contributed to regenerate some areas in Glasgow, but also to revitalize local communities, to reconnect people with nature, to generate opportunities for social interaction, to stimulate social cohesion or to support physical activity. Each of these achievements constitutes mechanisms to alleviate chronic stress associated to urban lifestyle and needs to be explored further to understand how they work and how they could be reinforced to become more effective.</p> <p><b>4. Indicator strengths.</b> Chronic stress is considered as a reliable indicator to assess physical and mental health and general wellbeing. In addition, it is appropriate to explore whether the exposition to a NBS contributes to mitigate stress.</p>
<b>Description of Additional Indicator Application</b>	<p>The tool selected and applied by Glasgow to measure the chronic stress indicator in the Stalled Spaces programme is <b>the 10-items Perceived Stress Scale</b> (Cohen et al., 1983) included in a survey with other indicators specifically chosen to assess the multiple benefits associated to the implementation of this programme. This scale is a self-report measure that provides psychological subjective data. In particular, it intends to capture the degree to which persons perceive situations in their daily life as excessively stressful in relation to their ability to cope with them.</p> <p>Methodology and data analysis require high expertise in psycho-social research but quantitative data collection does not require expertise.</p>
<b>Stakeholders involved</b>	Glasgow City Council; Connecting Nature partners; Data collection experts (responsible for collecting subjective psychological data)
<b>Barriers encountered and lessons learned</b>	<p><b>Barriers encountered</b></p> <p>Given the complex psychophysiological pathways of stress, measurement is usually approached holistically through collection of both subjective psychological (i.e., subjective rating scales, self-report measures) and objective physiological data (most frequently, salivary analysis due to the validity, reliability and ease of collection of salivary data). However, collecting biochemical data for evaluating a NBS is considered as a major challenge by the majority of cities for two main reasons: (i) data collection and analysis of biochemical samples require high clinical expertise, resources and capacities which are frequently difficult to acquire for cities; (ii) barriers usually encountered during fieldwork planning -and in particular those related to the recruitment of participants - for any study increase when clinical procedures are included in the design. This means that this objective physiological measure is feasible in the experimental research usually conducted by academic and health organizations, but not in the frame of a routine evaluation conducted by cities.</p> <p><b>Lessons learned</b></p> <ol style="list-style-type: none"> <li>1. The experience of Glasgow has demonstrated that it is essential to provide a detailed description of the characteristics of the NBS under evaluation and, in particular, of the activities deployed in it (i.e., gardening, urban gyms,</li> </ol>

	<p>play spaces...). The high diversity of uses allocated to the Stalled Spaces in Glasgow constitutes an unexceptional opportunity to identify which activities have a most positive impact in the stress alleviation (i.e., comparing activities that enhance physical activity with those that promote social interaction).</p> <ol style="list-style-type: none"> <li>2. In order to gain a holistic understanding of the NBS impact on the physical and mental health, it is also recommended to measure this indicator in combination with other indicators that could contribute to enrich data analysis and interpretation. In particular, it is suggested to also collect data about place attachment; general wellbeing and happiness; and depression and anxiety.</li> <li>3. It is strongly recommended to collect data on symbolic / affective meanings assigned to NBS using participatory data collection methods and qualitative techniques. These data are useful to understand why and how the exposition to, and the engagement with, the NBS could contribute to alleviate chronic stress.</li> </ol>
<b>Case study authors</b>	<p>Adina Dumitru<sup>1</sup> (<a href="mailto:adina.dumitru@udc.es">adina.dumitru@udc.es</a>), David Tomé-Lourido<sup>1</sup>, Susana Pablo<sup>1</sup></p> <p><sup>1</sup>University of A Coruña, Spain</p>
<b>References</b>	<p>Cohen, S., Kamarck, T., and Mermelstein, R., 'A global measure of perceived stress', <i>Journal of Health and Social Behavior</i>, Vol. 24, No 4, 1983, pp. 385-396.</p> <p>Cohen, S., Janicki-Deverts, D., and Miller, G. E., 'Psychological stress and disease', <i>Journal of the American Medical Association</i>, Vol. 298, No 14, 2007, pp. 1685-1687.</p> <p>Glasgow City Council, <i>Open Space Strategy</i>, 2020.</p> <p>Hammen, C., 'Stress and Depression', <i>Annual Review of Clinical Psychology</i>, Vol. 1, 2005, pp. 293-319.</p> <p>Kaplan, S., 'The Restorative Benefits of Nature: Toward an Integrative Framework', <i>Journal of Environmental Psychology</i>, Vol. 15, 1995, pp. 169-182.</p> <p>Klein, E.M., Brähler, E., Dreier, M., Reinecke, L., Müller, K.W., Schmutzer, G.G., Wölfling, K., and Beutel, M.E., 'The German version of the Perceived Stress Scale – psychometric characteristics in a representative German community sample', <i>BMC Psychiatry</i>, Vol. 16, 2016, pp. 1-10.</p> <p>Ulrich, R.S., Simons, R.F., Losito, B.D., Fiorito, E., Miles, M.A., and Zelson, M., 'Stress recovery during exposure to natural and urban environments', <i>Journal of Environmental Psychology</i>, Vol. 11, No 3, 1991, pp. 201-230.</p> <p>White, J.T. and Bunn, C., 'Growing in Glasgow: Innovative practices and emerging policy pathways for urban agriculture', <i>Land Use Policy</i>, Vol. 68, 2017, pp. 334-344.</p>



**Figure 5-23.** Stalled Spaces Programme (© Glasgow City Council).

#### 5.2.12 Health and Wellbeing – Perceived chronic loneliness

NBS Name and Location	Bellahouston Demonstration Garden Glasgow, Scotland
<b>Brief description of NBS</b>	<p>Bellahouston Demonstration Garden was established in the city of Glasgow, providing allotment-style growing spaces to be used by different charities and educational establishments (Hölscher et al., 2019; White and Bunn, 2017). The NBS arises from the Allotment and Neighbourhood and Sustainability strategies, carried out by the <a href="#">Glasgow City Council</a>, highlighting the restorative and therapeutic benefits of gardening, due to social interaction in the community (White and Bunn, 2017).</p> <p>The objective of this growing space located in the walled Garden at Bellahouston Park is twofold, on the one hand to provide healthy and sustainable food to the neighbours, and on the other hand to create a community space with social and health benefits for the citizens of Glasgow.</p>
<b>Additional Indicators of relevance</b>	<p><b>22.9 Perceived chronic loneliness</b></p> <p>Within <a href="#">Connecting Nature</a>, this indicator is conceptualized as a subjective experience of being socially isolated and absent both relational and collective connectedness (Russell et al., 1980).</p>

<b>Explanation for selection of Additional Indicators</b>	<p>The strategies implemented for the creation of demonstration gardens and growing spaces in Glasgow seek to promote social interaction and engaging people who felt isolated from the community (White and Bunn, 2017). Social isolation has a lasting impact on health and wellbeing (e.g., increased levels of stress, depression, or cardiovascular concerns) (Holt-Lunstad et al., 2010; Holt-Lunstad et al., 2015; Pantell et al., 2013), while social cohesion and green space are associated with positive outcomes like reduced smoking, alcohol consumption, obesity, or cognitive decline (Jennings and Bamkole, 2019; Wendelboe-Nelson et al., 2019).</p> <p>Green spaces contribute to social cohesion through fostering positive social interactions and social engagement (Jennings and Bamkole, 2019). Natural features also enhance feelings of place attachment and identity, promoting a sense of community that contributes to a decrease in feelings of loneliness (Prezza et al., 2001). A lower presence of green spaces in people's living environment was found to be related to greater feelings of loneliness and perceived shortage of social support (Maas et al., 2009). The association between green spaces, perceived social support and loneliness was found to be the strongest in highly urbanized areas (Maas et al., 2009).</p> <p>These research results, as well as the existing reality in the city led the Connecting Nature team to consider Chronic loneliness as a significant indicator to know the influence of the Bellahouston Demonstration Garden (Figure 5-24) on the well-being of its users.</p>
<b>Description of Additional Indicator Application</b>	<p>The indicator is assessed using a standardized quantitative instrument: The Three-Item Loneliness Scale (Hughes et al., 2004). This tool is a short form of the revised UCLA Loneliness scale (Russell et al., 1980) which measures the experience of loneliness. This scale includes three items measured on a 3-point Likert scale (1 = hardly ever; 2 = some of the time; 3 = often). For final scoring purposes, each person's scale responses to the three items are summed, with higher scores indicating greater experienced loneliness (Hughes et al., 2004).</p> <p>Methodology and data analysis require high expertise in psycho-social research but quantitative data collection requires no expertise. During the Connecting Nature project, the data gathering is conducted after the NBS implementation, but it allows making comparisons between different areas of the city or population groups (i.e., users vs no users). It is suggested to conduct two data collection waves to assess the longitudinal effects over time.</p>
<b>Stakeholders involved</b>	<p><a href="#">Connecting Nature</a>; <a href="#">Glasgow City Council</a>; <a href="#">Glasgow Community Planning Partnership</a>; Data collection experts</p>
<b>Barriers encountered and lessons learned</b>	<p>Although the officers leading the Food Growing Strategy were aware that the Bellahouston Demonstration Garden provided social, environmental, health and economic benefits, they had difficulties both in reflecting these advantages in official papers,</p>

	<p>and in holding conversations with the community and funding bodies (Hölscher et al., 2019).</p> <p>Therefore, within the Connecting Nature project a suitable business model was identified to scale up and replicate the project to other areas of the city (van de Sijpe et al. 2019). In this way, the Connecting Nature project provided the knowledge to develop food growing business within the Food Growing Strategy of the city council, conducting conversations with the community and identifying possible funding routes.</p>
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**Figure 5-24.** Bellahouston Demonstration Garden (© Glasgow City Council).

### 5.3 Conclusions

The case studies herein illustrate the strength of the 'buffet' style approach of the NBS impact indicator framework presented in this handbook. The inherent heterogeneity of NBS – in type, form and scale of application – preclude a one-size-fits-all approach to NBS impact assessment. In this context, the Recommended indicators provide a suggested minimum suite of indicators in order to obtain a holistic assessment of NBS performance and impact, with the selection of specific Additional indicators serving to address specific concerns and thus augment the achieved understanding. The preceding case studies show how a combination of Recommended and Additional indicators may be applied to a specific NBS in order to develop a comprehensive understanding of NBS performance and impact, thereby enabling adaptive management of the NBS asset.